

DRAFT

# ***Lower Duwamish Waterway Group***

***Port of Seattle / City of Seattle / King County / The Boeing Company***

## **LOWER DUWAMISH WATERWAY QUALITY ASSURANCE PROJECT PLAN FOR REMEDIAL DESIGN OF UPPER REACH:**

### **PRE-DESIGN INVESTIGATION**

**DRAFT**

**For submittal to**

**The U.S. Environmental Protection Agency**

**Region 10**

Seattle, WA

**November 25, 2019**

**Prepared by:**



200 West Mercer Street • Suite 401  
Seattle, Washington • 981199

in association  
with



1201 3rd Avenue • Suite 26000  
Seattle, Washington • 981011

***Lower Duwamish Waterway Group***

***Port of Seattle / City of Seattle / King County / The Boeing Company***

PDI QAPP  
i | November 2019

## TABLE OF CONTENTS

<b>1</b>	<b>Introduction .....</b>	<b>1</b>
<b>2</b>	<b>Project Objectives and Description .....</b>	<b>3</b>
2.1	Data Quality Objectives .....	3
2.2	Project Description and Schedule .....	11
<b>3</b>	<b>Project Organization and Responsibilities .....</b>	<b>14</b>
3.1	Project Management .....	15
3.2	Field Coordination .....	16
3.3	Quality Assurance/Quality Control .....	18
3.4	Laboratory Responsibilities .....	19
3.5	Data Management .....	21
3.6	Special Training/Certification .....	21
3.7	Documentation and Records .....	21
3.7.1	Field Observations .....	21
3.7.2	Laboratory Records .....	22
3.7.3	Data Reduction .....	27
3.7.4	Data Storage and Backup .....	27
<b>4</b>	<b>Data Generation and Acquisition for Sediment and Bank Analytical Samples .....</b>	<b>28</b>
4.1	Sampling Design for Sediment and Bank Samples .....	28
4.1.1	Tiered sample collection .....	28
4.1.2	Sediment sample depth intervals .....	28
4.1.3	Analytes by Sample Type .....	31
4.1.4	Phase I Sediment Sampling Design .....	34
4.1.5	Phases I and II Toxicity Testing Design .....	38
4.1.6	Phases II and III Sediment and Bank Sampling Design .....	39
4.2	Sediment Sampling Methods .....	41
4.2.1	Sediment Sampling Sequencing and Logistics .....	41
4.2.2	Target Sampling Locations .....	42
4.2.3	Surface Sediment Collection .....	42
4.2.4	Subsurface Sediment Collection .....	43
4.2.5	Sediment Collection for Toxicity Testing .....	43
4.3	Bank Sampling Methods .....	44
4.4	Diver-related Activities .....	44

4.5	Sample Identification.....	45
4.6	Sample Custody and Shipping Requirements .....	45
4.6.1	Sample Custody Procedures .....	46
4.6.2	Shipping Requirements.....	46
4.7	Decontamination Procedures.....	47
4.8	Field-generated Waste Disposal .....	48
4.9	Laboratory Methods for Sediment and Bank Samples.....	48
4.9.1	Laboratory Sample Handling .....	48
4.9.2	Analytical Methods .....	49
4.10	Sediment Chemistry Analytical Data Quality Objective and Criteria.....	56
4.11	Sediment Chemistry Quality Assurance/Quality Control.....	62
4.11.1	Sample Delivery Group .....	63
4.11.2	Laboratory Quality Control Samples.....	66
4.12	Sediment Toxicity Testing Quality Objectives and Quality Assurance/Quality .....	68
4.12.1	Laboratory Sediment Handling .....	68
4.12.2	Toxicity Test Evaluation Criteria .....	69
4.12.3	Data Quality Indicators.....	70
4.12.4	Sediment Toxicity Testing Quality Control Criteria .....	71
4.13	Instrument/Equipment Testing, Inspection, and Maintenance .....	72
4.14	Instrument/Equipment Calibration and Frequency .....	73
4.15	Inspection/Acceptance of Supplies and Consumables.....	73
4.16	Analytical Data Management .....	73
<b>5</b>	<b>Data Generation and Acquisition of Engineering PDI Elements.....</b>	<b>75</b>
5.1	Banks .....	75
5.1.1	Phase I Visual Inspection of Banks.....	75
5.1.2	Phase II Focused Topographic Surveys.....	77
5.2	Structure Inspections.....	77
5.3	Geotechnical Investigation .....	78
5.3.1	Geotechnical Investigation Design .....	79
5.3.2	Geotechnical Field Methods.....	80
5.3.3	Geotechnical Laboratory Methods .....	82
5.4	Specialized Surveys.....	83
<b>6</b>	<b>Data Validation and Usability .....</b>	<b>84</b>
6.1	Data Validation.....	84

6.2	Reconciliation with Data Quality Indicators .....	85
<b>7</b>	<b>Assessment and Oversight .....</b>	<b>86</b>
7.1	Compliance Assessments and Response Actions .....	86
7.1.1	Compliance Assessments .....	86
7.1.2	Response Actions for Field Sampling .....	86
7.1.3	Corrective Action for Laboratory Analyses .....	86
7.2	Reports to Management .....	87
7.3	Data Evaluation Reports .....	87
<b>8</b>	<b>References .....</b>	<b>89</b>

## TABLES

Table 2-1	DQOs for Phases I and II of the PDI in the Upper Reach .....	4
Table 2-2	DQOs for RAL Delineation in the Phase I Upper Reach PDI .....	5
Table 2-3	DQOs for Other Phase I and Phase II PDI Data Needs for the Upper Reach .....	7
Table 4-1	Sample Depth Intervals for Phase I .....	30
Table 4-2	Summary of Upper Reach Sampling Locations .....	37
Table 4-3	Identified Over-water Structures Outside of EAAs in the Upper Reach of the Lower Duwamish Waterway .....	39
Table 4-4	Sediment and Bank Analyses to be Conducted at each Analytical Laboratory ...	50
Table 4-5	Analytical Methods and Sample Handling Requirements for Sediment and Bank Samples .....	52
Table 4-6	Data Quality Indicators for Laboratory Analyses .....	57
Table 4-7	RAO 1, 2, and 4 COCs and Associated RL Goals and RALs for Sediment Samples .....	59
Table 4-8	RAO 3 COCs and Associated RL Goals and RALs for Individual 0–10-cm Sediment Samples .....	60
Table 4-9	Sample Mass Required per Analysis .....	62
Table 4-10	Laboratory Quality Control Sample Analysis Summary .....	64
Table 4-11	Sediment Conditions and Preferred Amphipod Test Species .....	68
Table 4-12	SMS Marine Biological Criteria .....	69
Table 4-13	Data Quality Indicators for Sediment Toxicity Testing .....	70
Table 5-1	Analytical Methods and Sample Handling Requirements for Geotechnical Samples .....	83

## FIGURES

Figure 1-1	Design Sampling Phases .....	2
Figure 3-1	Project Organization and Team Responsibilities .....	14
Figure 4-1	Federal Navigation Channel Design Sampling .....	31
Figure 4-2	Required analytes per ROD Table 27 and 28 .....	33

## MAPS

Map 1	Upper reach of the LDW (RM 3.0 to RM 5.0)
Map 2	Segment 1 (RM 3.0 to RM 3.5) Phase I locations, sediment RAL exceedances, bathymetry, and ROD Figure 18 remedial action areas
Map 3	Segment 2 (RM 3.5 to RM 4.05) Phase I locations, sediment RAL exceedances, bathymetry, and ROD Figure 18 remedial action areas
Map 4	Segment 3a (RM 4.05 to RM 4.35) Phase I locations, sediment RAL exceedances, bathymetry, and ROD Figure 18 remedial action areas
Map 5	Segment 3b (RM 3.35 to RM 4.75) Phase I locations, sediment RAL exceedances, bathymetry, and ROD Figure 18 remedial action areas
Map 6	Segment 4 (RM 4.75 to RM 5) Phase I locations, sediment RAL exceedances, bathymetry, and ROD Figure 18 remedial action areas
Map 7	DMMUs in Duwamish Yacht Club and Delta Marine
Map 8	Locations identified for dioxin/furan analysis

## APPENDICES

Appendix A	2019 Bathymetry Survey Results
Appendix B	Recommended Recovery Category Modifications Based on the 2019 Bathymetry Survey
Appendix C	Health and Safety Plan
Appendix D	Field Collection Forms
Appendix E	Analytical Methods and Reporting Limits
Appendix F	Standard Operating Procedures
Appendix G	Sampling Location Details

## ABBREVIATIONS

abbreviation	definition
%RSD	percent relative standard deviation
AET	apparent effects threshold
AFDW	ash-free dry weight
Anchor QEA	Anchor QEA LLC
AOC3	Third Amendment to the Administrative Order on Consent
AOC4	Fourth Amendment to the Administrative Order on consent
ARI	Analytical Resources, Inc.
ASCE	American Society of Civil Engineers
ASTM	American Society for Testing and Materials
BEHP	bis(2-ethylhexyl) phthalate
CCF	compaction correction factor
CFR	Code of Federal Regulations
COC	contaminant of concern
cPAH	carcinogenic polycyclic aromatic hydrocarbon
CPT	cone penetration testing
CRM	certified reference material
CSL	cleanup screening level
CV-AFS	cold vapor-atomic fluorescence spectroscopy
DCM	dichloromethane
DCP	dynamic cone penetrometer
DGPS	differential global positioning system
DL	detection limit
DMMP	Dredged Material Management Program
DMMU	dredged material management unit
DO	dissolved oxygen
DQI	data quality indicator
DQO	data quality objective
dw	dry weight
EAA	early action area
EC50	concentration that causes a non-lethal effect in 50% of an exposed population
EcoAnalysts	EcoAnalysts, Inc.
Ecology	Washington State Department of Ecology

EDL	estimated detection limit
EF	exceedance factor
EIM	Environmental Information Management
EPA	US Environmental Protection Agency
FC	field coordinator
FFP	full-flow penetrometer
FNC	federal navigation channel
GC/ECD	gas chromatography/electron capture detection
GC/MS	gas chromatography/mass spectrometry
GPC	gel permeation chromatography
Harold Benny	Harold L. Benny & Associates, Inc.
HDPE	high-density polyethylene
HPAH	high-molecular-weight polycyclic aromatic hydrocarbon
HRGC/HRMS	high-resolution gas chromatography/high-resolution mass spectrometry
HpCDD	heptachlorodibenzo- <i>p</i> -dioxin
HpCDF	heptachlorodibenzofuran
HxCDD	hexachlorodibenzo- <i>p</i> -dioxin
HxCDF	hexachlorodibenzofuran
ICP-MS	inductively coupled plasma-mass spectrometry
ID	identification
LAET	lowest apparent effects threshold
LC50	concentration that is lethal to 50% of an exposed population
LCS	laboratory control sample
LDC	Laboratory Data Consultants, Inc.
LDW	Lower Duwamish Waterway
LDWG	Lower Duwamish Waterway Group
LIDAR	light detection and ranging
LLOQ	lower limit of quantitation
LOQ	limit of quantitation
LPAH	low-molecular-weight polycyclic aromatic hydrocarbon
MDL	method detection limit
MHHW	mean higher high water
MLLW	mean lower low water
MOP	manual of practice
MS	matrix spike

MSD	matrix spike duplicate
NOAA	National Oceanic and Atmospheric Administration
NOEC	no-observed-effect concentration
OCDD	octachlorodibenzo- <i>p</i> -dioxin
OCDF	octachlorodibenzofuran
OSHA	Occupational Safety and Health Administration
PAH	polycyclic aromatic hydrocarbon
PARCCS	precision, accuracy, representativeness, completeness, comparability, and sensitivity
PCB	polychlorinated biphenyl
PDI	pre-design investigation
PDIWP	Pre-Design Investigation Work Plan
PeCDD	pentachlorodibenzo- <i>p</i> -dioxin
PeCDF	pentachlorodibenzofuran
PM	project manager
PPE	personal protective equipment
ppt	parts per thousand
PRC	performance reference compound
PSEP	Puget Sound Estuary Program
QA	quality assurance
QC	quality control
QAPP	quality assurance project plan
RAL	remedial action level
RAO	remedial action objective
RD	remedial design
RDWP	Remedial Design Work Plan
RI/FS	remedial investigation/feasibility study
RL	reporting limit
RM	river mile
ROD	Record of Decision
RPD	relative percent difference
RPM	remedial project manager
SCO	sediment cleanup objective
SCUM II	Sediment Cleanup User's Manual II
SDG	sample delivery group
SGS Axys	SGS Axys Analytical Services Ltd.

SIM	selective ion monitoring
SM	Standard Method
SMS	Washington State Sediment Management Standards
SOP	standard operating procedure
SPT	standard penetration testing
SQS	sediment quality standards
SVOC	semivolatile organic compound
TBT	tributyltin
TCDD	tetrachlorodibenzo- <i>p</i> -dioxin
TCDF	tetrachlorodibenzofuran
TEF	toxic equivalency factor
TEQ	toxic equivalent
TOC	total organic carbon
TM	task manager
UCT-KED	universal cell technology-kinetic energy discrimination
Vista	Vista Analytical Laboratory
VST	vane shear testing
WAC	Washington Administrative Code
Windward	Windward Environmental LLC
ww	wet weight

DRAFT

This page intentionally left blank.

# 1 Introduction

This quality assurance project plan (QAPP) describes the quality assurance (QA) objectives, methods, and procedures for pre-design investigation (PDI) sampling in the upper reach of the Lower Duwamish Waterway (LDW) (river mile [RM] 3.0 to RM 5.0) (Map 1). This work supports the remedial design for the upper reach per the Fourth Amendment to the Administrative Order on Consent (AOC4) for the LDW (EPA 2018). Sampling will include the collection and chemical analysis of sediment samples to delineate exceedances of sediment remedial action levels (RALs) presented in Tables 27 and 28<sup>1</sup> of the US Environmental Protection Agency (EPA) Record of Design (ROD) (EPA 2014b). Sampling will also include the collection of engineering data to provide the information needed to determine appropriate remedial technologies in remedial action areas, as well as banks and other information needed to design the area-specific remedy in the upper reach.

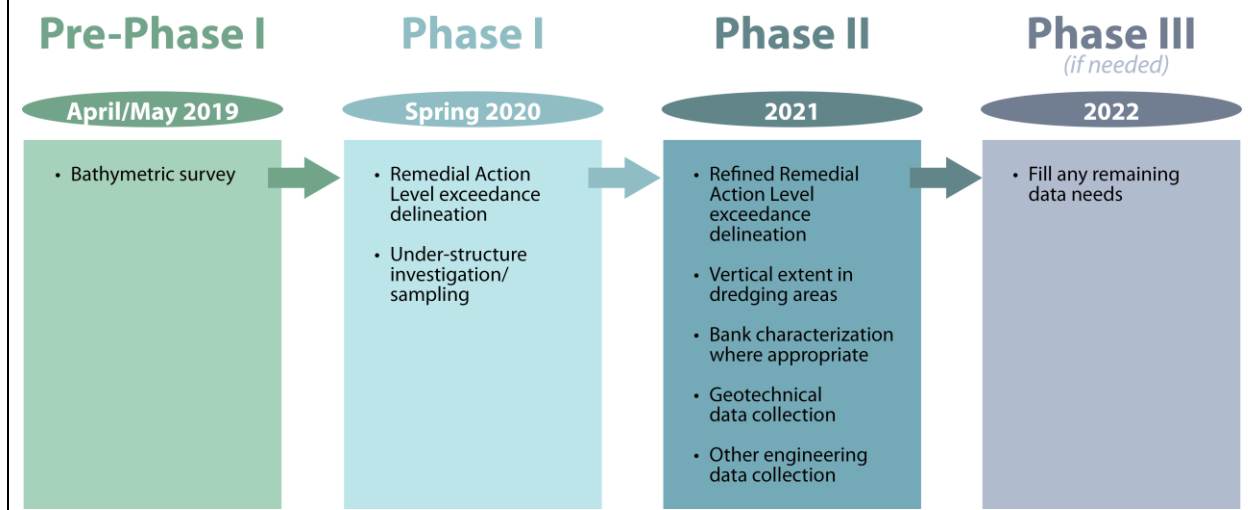
The Pre-Design Investigation Work Plan (PDIWP) (Windward and Anchor 2019) presented a conceptual study design for PDI sampling and provided the objectives, background, and the conceptual study design. This QAPP presents a more detailed study design, including project organization and schedule, sampling locations, field collection methods, laboratory analysis methods and procedures, data management protocols, and reporting requirements. This document was prepared in accordance with EPA's (2002) guidance on preparing QAPPs.

Design sampling will be done in phases (Figure 1-1). Phase I will involve the collection of data needed to delineate the extent of RAL exceedances in surface (0- to 10-cm) and near-surface (0- to 45-cm and 0- to 60-cm) sediment in order to identify preliminary remedial action areas and make preliminary technology assignments. Phase II will involve the collection of data to further refine the delineation of RAL exceedances (as needed), to assess the vertical distribution of contamination in dredge and cap areas, and to acquire area-specific engineering information needed for design, including banks. Phase III will be conducted if data needs remain after Phase II. Following each phase of sampling, a data evaluation report will be prepared to interpret the information and guide the development of subsequent design sampling phases.

---

<sup>1</sup> ROD Table 27 is titled *Selected Remedy RAO 3 RALs* and Table 28 is titled *Remedial Action Levels, ENR Upper Limits, and Areas and Depths of Application*.

**Figure 1-1**  
**Design Sampling Phases**



This QAPP provides detailed methods and protocols for all phases and types of design data collection. Details regarding study design for Phase I design sampling, including location coordinates and rationale, are also provided. Based on the Phase I results, QAPP addenda will be prepared to present detailed locations and other specifics for Phase II and, if needed, Phase III.

This QAPP is organized into the following sections:

- Section 2 – Project Objectives and Description
- Section 3 – Project Organization and Responsibilities
- Section 4 – Data Generation and Acquisition for Sediment and Bank Samples
- Section 5 – Data Generation and Acquisition of Engineering PDI Elements
- Section 6 – Data Validation and Usability
- Section 7 – Assessment and Oversight
- Section 8 – References

This QAPP is supported by five appendices, as follows.

- Appendix A – 2019 Bathymetry Results
- Appendix B – Recommended Recovery Category Modifications based on the 2019 Bathymetry Survey
- Appendix C – Health and Safety Plan
- Appendix D – Field Forms
- Appendix E – Analytical Methods and Reporting Limits (RLs)
- Appendix F – Standard Operating Procedures (SOPs)
- Appendix G – Sampling Location Details

## 2 Project Objectives and Description

This section presents an overview of the data quality objectives (DQOs) and the scope of the design sampling.

### 2.1 Data Quality Objectives

The PDI has two objectives: 1) to collect data needed to delineate remedial action areas, and 2) to support remedial technology applications in designing a remedy consistent with the ROD (ROD Tables 27 and 28 and ROD Figures 19, 20, and 21; EPA 2014b).<sup>2</sup>

DQOs were identified in the PDIWP (Windward and Anchor 2019) for Phases I and II (Tables 2-1, 2-2, and 2-3). Seven of the eight Phase I DQOs are focused on delineating exceedances of the RALs listed in ROD Tables 27 and 28 (EPA 2014b); the eighth DQO involves a visual inspection of the upper reach banks. Phase II DQOs involve additional refinement of the extent of RAL exceedances (including under-pier areas), as needed, and collection of engineering data (including vertical contamination and bank characterization) required for design of the remedy in the upper reach. Phase III will be conducted if data needs remain following Phase II or are otherwise identified during preparation or EPA review of the 30% design. Phase III DQOs will be presented in the QAPP addendum for Phase III, if needed.

---

<sup>2</sup> ROD Figures 19, 20, and 21 are titled *Intertidal Areas – Remedial Technology Applications*, *Subtidal areas – Remedial Technology Applications*, and *Intertidal and Subtidal Areas – Natural Recovery Application*, respectively.

**Table 2-1**  
**DQOs for Phases I and II of the PDI in the Upper Reach**

Phase I	Phase II
DQO1 – Delineate 0–10-cm RAL exceedances in Recovery Category 2/3 DQO2 – Delineate 0–10-cm RAL exceedances in Recovery Category 1 DQO3 – Delineate 0–45-cm intertidal RAL exceedances in Recovery Category 2/3 DQO4 – Delineate 0–45-cm intertidal RAL exceedances in Recovery Category 1 DQO5 – Delineate 0–60-cm PCB RAL exceedances in potential vessel scour areas in Recovery Category 2/3 DQO6 – Delineate 0–60-cm RAL exceedances in Recovery Category 1 DQO7 – Delineate RAL exceedances in shoaling areas DQO8 – Conduct a visual bank inspection in the upper reach	DQO9 – Investigate areas under over-water structures and sample if feasible to delineate RAL exceedances DQO10 – Further delineate RAL exceedances, as needed for unbounded areas DQO11 – Assess chemical and physical characteristics of banks (including topographic survey), as needed, depending on remedial technology selected for adjacent sediment and whether bank is erosional DQO12 – Delineate vertical elevation of RAL exceedances in dredge (and dredge/cap) areas and collect vertical information in cap areas DQO13 – Collect geotechnical data as needed depending on technology proposed and/or physical characteristics of remedial action areas DQO14 – Collect other engineering applicable data as needed (e.g., structures inspection, utility location verification, thickness of sediment on top of riprap layers)

Notes:

cm: centimeter

DQO: data quality objective

PCB: polychlorinated biphenyl

RAL: remedial action level

**Table 2-2**  
**DQOs for RAL Delineation in the Phase I Upper Reach PDI**

DQO Step	DQO 1	DQO 2	DQO 3	DQO 4	DQO 5	DQO 6	DQO 7
STEP 1: State the problem.	Additional sediment data are needed to delineate RAL exceedances in the 0- to 10-cm interval to identify remedial action areas.		Additional sediment data are needed to delineate RAL exceedances in the 0- to 45-cm interval to identify remedial action areas.		Additional sediment data are needed to delineate RAL exceedances in the 0- to 60-cm interval to identify remedial action areas.		Additional sediment data are needed to delineate RAL exceedances in the shoals in the FNC to identify remedial action areas.
STEP 2: Identify the goals of the study.	Collect sufficient data in sediment intervals identified in ROD Table 28 to identify the following in the Phase I data evaluation report: 1) preliminary remedial action area boundaries and technologies, and 2) data needs for Phase II.						
STEP 3: Identify the information inputs.	RI/FS and post-FS sediment data from the LDW were used to identify existing locations of RAL exceedances in the upper reach. Dredge characterization data were used to identify the areas subject to frequent dredging and the sediment quality in these areas. Upland information was used to identify areas with potential sources of COCs. 2019 bathymetry and recovery category information was used to identify where RALs apply.						
STEP 4: Define the boundaries of the study.	The boundary of the study has been defined by AOC4 as the upper reach (RM 3 to RM 5).						
STEP 5: Develop the analytical approach.	Sample analysis will be tiered. Tier 1 samples will be analyzed for chemicals with RALs, as described in ROD Table 28. The Tier 1 results will be used to determine which analytes are appropriate for the analysis of Tier 2 samples.						
STEP 6: Specify performance or acceptance criteria.	Performance or acceptance criteria are described in Section 4.11, including field QC samples and laboratory QC samples. DQIs for laboratory analyses (i.e., PARCCS) will be met, as described in Section 4.10.						

**Table 2-2**  
**DQOs for RAL Delineation in the Phase I Upper Reach PDI**

DQO Step	DQO 1	DQO 2	DQO 3	DQO 4	DQO 5	DQO 6	DQO 7
STEP 7: Develop the detailed plan for obtaining data.	Tier 1 and Tier 2 sediment samples will be collected at the same time. Tier 1 locations were selected to 1) reoccupy locations with RAL exceedances based on RI/FS and post-FS data; 2) bound areas with more than one existing RAL exceedance and documented historical sources, recent (< 10 years old) data with RAL exceedances, and EFs greater than approximately 2; and 3) provide spatial coverage in areas with limited existing data and areas where there are reasons to believe that RAL exceedances may exist.		Tier 1 and Tier 2 sediment samples will be collected at the same time. Samples in the 0- to 45-cm interval will be collected in the intertidal area, generally from the same locations as the 0- to 10-cm samples in those areas.		Tier 1 and Tier 2 sediment samples will be collected at the same time. Samples in the 0- to 60-cm interval will be collected in the subtidal area, generally from the same locations as the 0- to 10-cm samples in those areas.		Tier 1 and Tier 2 sediment samples will be collected at the same time. Samples will be collected in FNC in areas that are shallower than -15 ft MLLW. The depth of the interval will be based on the depth of the shoal as shown in Figure 4-1.

Notes:

AOC4: Fourth Amendment to the Administrative Order on Consent

COC: contaminant of concern

DQI: data quality indicator

DQO: data quality objective

EF: exceedance factor

FNC: federal navigation channel

LDW: Lower Duwamish Waterway

MLLW: mean lower low water

PARCCS: precision, accuracy, representativeness, completeness, comparability, and sensitivity

PDI: pre-design investigation

QC: quality control

RAL: remedial action level

RI/FS: remedial investigation/feasibility study

RM: river mile

ROD: Record of Decision

**Table 2-3**  
**DQOs for Other Phase I and Phase II PDI Data Needs for the Upper Reach**

DQO Step	DQO 8	DQO 9	DQO 10	DQO 11	DQO 12	DQO 13	DQO 14
STEP 1: State the problem.	Visual observations are needed to identify key features along the banks of the upper reach.	Sampling has not been conducted under over-water structures.	Preliminary boundaries may need to be refined following Phase I data collection.	Additional information needed to assess banks will depend on remedial technology selected for adjacent sediment and whether the bank is erosional.	In dredge and dredge cap areas, additional sediment data are needed to delineate the depth of RAL exceedances. In capping areas, additional vertical contamination information is needed to inform the design of caps.	Geotechnical data are needed to evaluate the remedial technology proposed and/or physical characteristics of remedial action areas.	Other engineering data are needed to design the remedy (e.g., structures inspection, utility location verification, thickness of sediment on top of riprap layers).
STEP 2: Identify the goals of the study.	Visually inspect and document the presence and condition of bank armoring, vegetation, and other features to be considered during RD.	Sample beneath over-water structures, where feasible, to delineate RAL exceedances.	Collect data in sediment intervals identified in ROD Table 28 to bound or refine the horizontal extents of remedial action areas.	Collect bank characterization data and topographic survey data as needed for design.	Collect data to bound the vertical extents of contamination in dredge and dredge/cap areas, and collect vertical data as needed for cap design in capping areas.	Collect data required to evaluate remedial actions for dredge cut design, slope areas, actions adjacent to structures, and where caps will be placed.	Collect other engineering data needed to design the remedy.

**Table 2-3**  
**DQOs for Other Phase I and Phase II PDI Data Needs for the Upper Reach**

DQO Step	DQO 8	DQO 9	DQO 10	DQO 11	DQO 12	DQO 13	DQO 14
STEP 3: Identify the information inputs.	Existing information collected during the RI and Waterway Users Survey	Waterway Users Survey information on structures, structure access and conditions identified during the Phase I structures inspection, and 2019 bathymetry and recovery category information	RI/FS and post-FS data as well as Phase I PDI data	RI/FS and post-FS data as well as Phase I PDI data and bank visual inspection data	RI/FS and post-FS data as well as Phase I PDI data	Preliminary remedial action area boundaries identified in Phase I, existing geotechnical data, structure locations, and 2019 bathymetry	Preliminary remedial action area boundaries identified in Phase I
STEP 4: Define the boundaries of the study.	The boundary of the study has been defined in AOC4 as the upper reach (RM 3 to RM 5).						

**Table 2-3**  
**DQOs for Other Phase I and Phase II PDI Data Needs for the Upper Reach**

DQO Step	DQO 8	DQO 9	DQO 10	DQO 11	DQO 12	DQO 13	DQO 14
STEP 5: Develop the analytical approach.	Not applicable	Sediment samples will be analyzed for chemicals with RALs, per ROD Table 28.	Samples will be analyzed for chemicals with RAL exceedances in nearby samples in Phase I.	Samples will be analyzed for chemicals based on the results of Phase I. Topographic survey methods will be provided in a Survey QAPP <sup>1</sup> addendum.	Samples will be analyzed for chemicals based on Phase I results.	Geotechnical sample locations will be provided in the Phase II QAPP Addendum. Geotechnical analyses will follow standard ASTM testing protocols.	Not applicable
STEP 6: Specify performance or acceptance criteria.	Not applicable	Performance or acceptance criteria for chemistry samples are described in Section 4.11, including field QC samples and laboratory QC samples. DQIs for laboratory analyses (i.e., PARCCS) will be met, as described in Section 4.10.		Chemistry performance or acceptance criteria as described for DQOs 9 and 10. Topographic survey data performance or acceptance criteria will be provided in a Survey QAPP <sup>1</sup> addendum.	Performance or acceptance criteria as described for DQOs 9 and 10.	Performance criteria for geotechnical testing as described in each relevant ASTM standard for the test method used.	Not applicable

**Table 2-3**  
**DQOs for Other Phase I and Phase II PDI Data Needs for the Upper Reach**

DQO Step	DQO 8	DQO 9	DQO 10	DQO 11	DQO 12	DQO 13	DQO 14
STEP 7: Develop the detailed plan for obtaining data.	Details on bank visual inspections are provided in Section 5.1.1.	Detailed plans for obtaining data will be provided in Phase II Sampling QAPP Addenda.					Data will be obtained in accordance with standard engineering practices.

Notes:

*Quality Assurance Project Plan: Pre-Design Surveys of the Lower Duwamish Waterway Upper Reach* (Anchor and Windward 2019b)

AOC4: Fourth Amendment to the Administrative Order on Consent

ASTM: American Society for Testing and Materials

DQI: data quality indicator

DQO: data quality objective

PARCCS: precision, accuracy, representativeness, completeness, comparability, and sensitivity

PDI: pre-design investigation

QAPP: quality assurance project plan

QC: quality control

RAL: remedial action level

RD: remedial design

RM: river mile

ROD: Record of Decision

## 2.2 Project Description and Schedule

To meet the DQOs, the conceptual design sampling plan described in the PDIWP (Windward and Anchor 2019) identified the need for the following types of data, which will be collected per the methods outlined in this QAPP (or in an addendum to the *Quality Assurance Project Plan: Pre-Design Surveys of the Lower Duwamish Waterway Upper Reach* (Anchor and Windward 2019b), herein referred to as the Survey QAPP, as noted).

- Phase I
  - Sediment chemistry data in sediment intervals with RALs (0 to 10 cm, 0 to 45 cm, and 0 to 60 cm) to delineate RAL exceedances (DQOs 1 through 7)
  - Visual bank characterization data of the entire upper reach to identify key physical features that may factor into remedial design (RD), general shoreline conditions (e.g., armoring), and vegetation (DQO 8)
  - Toxicity testing at select locations (DQOs 1 and 2)
- Phase II or III
  - Additional RAL delineation as needed (DQOs 9 and 10)
  - Vertical (> 60 cm) extent data to evaluate depth of dredge prisms in dredge areas (DQO 12)
  - Vertical (> 60 cm) data below caps for cap design modeling (DQO 12)
  - Additional toxicity testing data in areas where only benthic RAL exceedances exist (DQO 1 and 2)
  - Bank characterization where needed and focused topographic survey data (as described in the upcoming Survey QAPP addendum<sup>3</sup>) in upper reach bank areas where needed (DQO 11)
  - Area-specific sediment geotechnical properties, including geological characterization, sediment index, and sediment strength and consolidation properties (DQO 13), to:
    - Determine sediment stability and stable dredge cut side-slope requirements.
    - Characterize sediment dredgeability.
    - Support sediment consolidation assessment for cap design.
    - Support contractor's selection of dredge equipment.
    - Support design of sediment handling, transport, dewatering, treatment systems, and disposal requirements.
  - Specialized surveys as appropriate to characterize utilities and/or debris (as described in the Survey QAPP addendum) and to measure thickness of sediment

---

<sup>3</sup> The Survey QAPP addendum will be developed in parallel with the Phase II QAPP addendum.

overlying bank armoring (as will be described in the Phase II QAPP addendum)  
(DQO 14)

All data collection and sampling activities will be conducted in conformance with the HSP. This information will be collected and reported per the following schedule, as outlined in the PDIWP (Windward and Anchor 2019).

Upon approval of the QAPP or QAPP addendum, PDI field work will be completed in accordance with the schedule provided in the Remedial Design Work Plan (RDWP) (180 days allotted to each phase of field collection, chemical analysis, and validation), unless otherwise approved by EPA (Anchor and Windward 2019a). Phase I field work is anticipated to begin in spring 2020, depending on approval of the QAPP.

Within a design sampling phase, two tiers of analytical rounds are anticipated in addition to potential toxicity testing (see Section 4.1.1). Following receipt of unvalidated analytical results from Tier 1, a working meeting with EPA will be held to determine which archive samples will be analyzed in Tier 2. A data package will be submitted to EPA after data from Tiers 1 and 2 including all toxicity results have been received, and the chemistry results have been validated. This Phase I data package will be due to EPA 10 days after the receipt of toxicity data and Tier 1 and 2 sampling data from the validator.

PDI data evaluation reports will be submitted to EPA following Phases I and II of the PDI. The PDI data evaluation reports will present and interpret the data (including existing data), define preliminary remedial action area boundaries, assign preliminary remedial technologies to these areas, and identify remaining potential data needs. The Phase I PDI data evaluation report will be submitted to EPA 60 days after submittal of the Phase I PDI data package. The Phase II PDI data evaluation report will be submitted to EPA 45 days after submittal of the Phase II PDI data package. EPA comments on the data evaluation reports will be reflected in subsequent deliverables, rather than submitted in revised versions. If Phase III design sampling is conducted, a Phase III PDI data evaluation report will be submitted to EPA 45 days after submittal of the Phase III data package; the Phase III results will be incorporated into 90% design.

Based on the Phase I PDI data evaluation report, details regarding Phase II design sampling will be presented in a QAPP addendum, including specific Phase II design sampling locations and rationale, depths, analytes, geotechnical data, and additional engineering data and information needed to design remedies in specific areas. If needed, a Phase III QAPP addendum will be prepared following the Phase II data evaluation report and EPA comments on the 30% design.

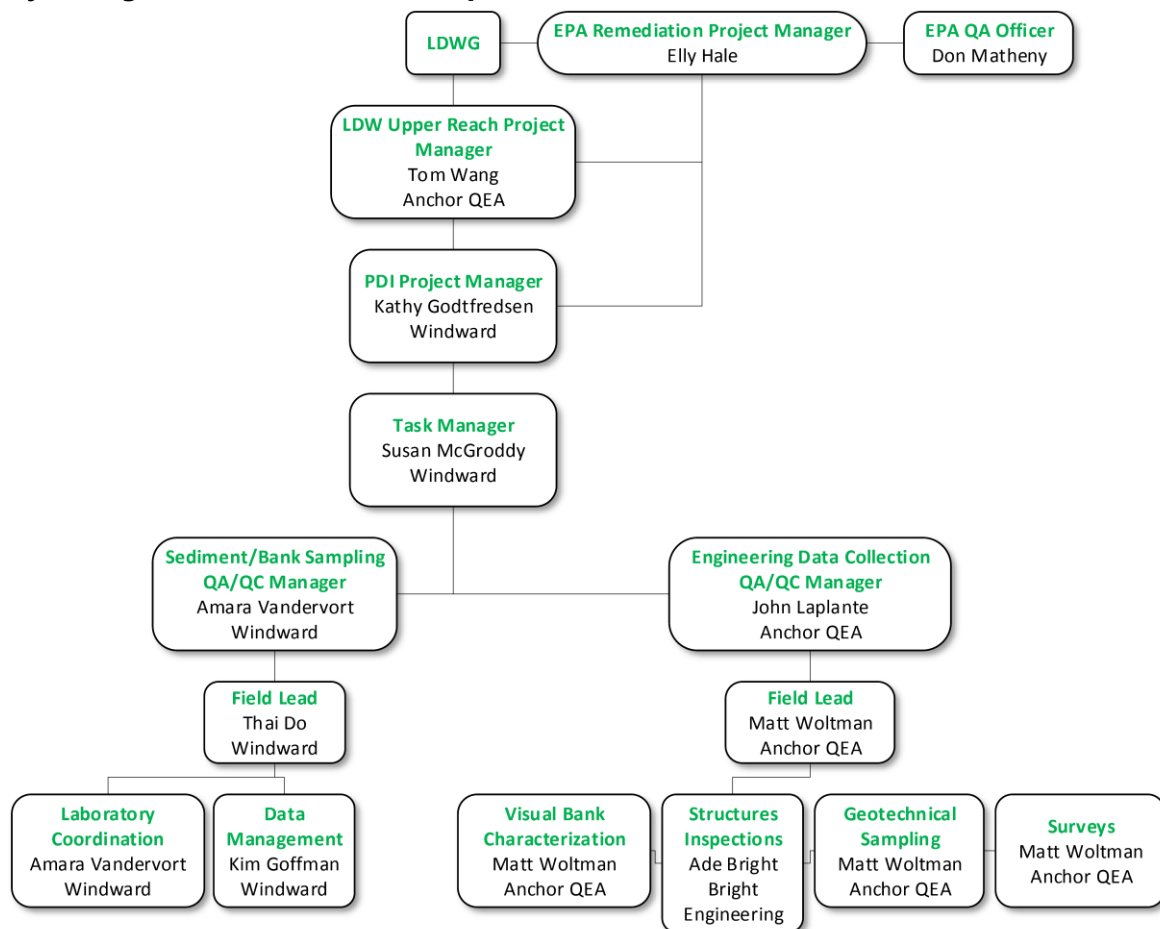
The 2019 bathymetry data, summarized in Appendix A, have been incorporated into all of the maps in this QAPP to aid in determining sampling locations. In addition, these data were used to propose minor changes to recovery categories from RM 3.0 to RM 5.0, as summarized in Appendix B. Any final revisions to the recovery categories will be documented in the Phase II

data evaluation report. This timing will allow for consideration of Phase I and II sediment data in establishing the final recovery category boundaries.

### 3 Project Organization and Responsibilities

The overall project organization and the individuals responsible for the various tasks required for PDI sampling and analysis are shown in Figure 3-1. Responsibilities of project team members, as well as laboratory project managers (PMs), are described in the following sections.

**Figure 3-1**  
**Project Organization and Team Responsibilities**



#### Suppliers

**Analytical Chemistry:** Analytical Resources, Inc., OnSite Environmental Inc., SGS Axys Analytical Services Ltd., Vista Analytical Laboratory  
**Bathymetric/Debris Surveying:** Northwest Hydro, Inc.  
**Data Validation:** Laboratory Data Consultants, Inc.  
**Geotechnical Analysis:** Harold L. Benny & Associates, Inc.  
**Geotechnical Drilling:** Gregory Drilling Inc.  
**Sampling Vessels/Divers:** Research Support Services, Inc., Science Engineering and the Environment, LLC, Gravity Marine Services  
**Topographic Surveying:** True North Land Surveying, Inc.

### 3.1 Project Management

Both the Lower Duwamish Waterway Group (LDWG) and EPA are involved in all aspects of this project, including discussion, review, and approval of this QAPP and interpretation of the results of the investigation. Elly Hale is the EPA remedial project manager (RPM) for the PDI and RD for the upper reach.

Tom Wang is the Anchor QEA LLC (Anchor QEA) PM for the upper reach RD. In this capacity, he will be responsible for providing oversight for planning and coordination, work plans, all project deliverables, and performance of the administrative tasks needed to provide timely and successful completion of the project. He will also be responsible for coordinating with LDWG and EPA on schedule, deliverables, and other administrative details. Mr. Wang can be reached as follows:

Mr. Tom Wang  
Anchor QEA LLC  
1201 3<sup>rd</sup> Avenue, Suite 2600  
Seattle, WA 98101  
Telephone: 206.903.3314  
E-mail: [twang@anchorqea.com](mailto:twang@anchorqea.com)

Kathy Godtfredsen is the Windward Environmental LLC (Windward) PM for the upper reach PDI. In this capacity, she will be responsible for PDI project coordination, and for providing oversight for planning and coordination, PDI-related project deliverables, and performance of the administrative tasks needed to provide timely and successful completion of the PDI. She will also be responsible for coordinating with LDWG and EPA on PDI-related details. Dr. Godtfredsen can be reached as follows:

Dr. Kathy Godtfredsen  
Windward Environmental LLC  
200 West Mercer Street, Suite 401  
Seattle, WA 98119  
Telephone: 206.577.1283  
E-mail: [kathyg@windwardenv.com](mailto:kathyg@windwardenv.com)

Susan McGroddy (Windward) is the task manager (TM) for the PDI. As TM, she will be responsible for communicating with the Windward PM on the progress of project tasks, conducting detailed planning and coordination, and monitoring and communicating to the Windward PM any deviations from the QAPP. Significant deviations from the QAPP will be further reported to representatives of LDWG and EPA. Dr. McGroddy can be reached as follows:

Dr. Susan McGroddy  
Windward Environmental LLC

200 West Mercer Street, Suite 401  
Seattle, WA 98119  
Telephone: 206.812.5421  
E-mail: [susanm@windwardenv.com](mailto:susanm@windwardenv.com)

## 3.2 Field Coordination

Thai Do is the field coordinator (FC) for Windward and will be responsible for managing field sampling activities and general field and QA/quality control (QC) oversight. He will oversee sample collection, preservation, and holding times, and will coordinate delivery of environmental samples to the designated laboratories for chemical analyses. Mr. Do will report deviations from this QAPP to the TM and PMs for consultation. Significant deviations from the QAPP will be further reported to representatives of LDWG and EPA. Mr. Do can be reached as follows:

Mr. Thai Do  
Windward Environmental LLC  
200 West Mercer Street, Suite 401  
Seattle, WA 98119  
Telephone: 206.812.5407<sup>4</sup>  
Email: [thaid@windwardenv.com](mailto:thaid@windwardenv.com)

Matt Woltman is the geotechnical, engineering field inspection, and surveying field coordinator for Anchor QEA. In this capacity, he will be responsible for managing geotechnical sampling, engineering field inspections (including visual bank characterization and structure inspection efforts), and the surveys (as described in Section 5 and in the Survey QAPP addendum).

Mr. Woltman will oversee geotechnical sample collection, processing, and delivery of samples to the designated laboratories for geotechnical analyses. He will report deviations from QAPPs to the TM and PM for consultation. Significant deviations from the QAPPs will be further reported to representatives of LDWG and EPA. Mr. Woltman can be reached as follows:

Mr. Matt Woltman  
Anchor QEA LLC  
1201 3<sup>rd</sup> Avenue, Suite 2600  
Seattle, WA 98101  
Telephone: 206.903.3327  
E-mail: [mwoltman@anchorgea.com](mailto:mwoltman@anchorgea.com)

---

<sup>4</sup> This is Mr. Do's office phone number. A mobile phone number will be provided prior to field sampling.

Mr. Woltman will work with Ade Bright with Bright Engineering Inc. on the structures inspections. Mr. Bright can be reached as follows:

Mr. Ade Bright  
Bright Engineering Inc.  
1809 7th Ave #1100  
Seattle, WA 98101  
Telephone: 206.625.3777  
E-mail: [ab@brighteng.com](mailto:ab@brighteng.com)

Eric Parker is the primary boat captain. He will be responsible for operating the boat and will coordinate closely with the FC to collect samples in accordance with the methods and procedures presented in this QAPP. Mr. Parker can be reached as follows:

Mr. Eric Parker  
Research Support Services  
321 NE High School Rd. Suite D3/563  
Bainbridge Island, WA 98110  
Mobile: 206.550.5202  
Email: [eparker@rssincorporated.com](mailto:eparker@rssincorporated.com)

Shawn Hinz and Tim Thompson will serve as boat captains for additional vessel support. Each will be responsible for operating his boat and will coordinate closely with the FC and the PMs to collect samples in accordance with the methods and procedures presented in this QAPP. Mr. Hinz and Mr. Thompson can be reached as follows:

Mr. Shawn Hinz  
Gravity Consulting LLC  
32617 Southeast 44<sup>th</sup> Street  
Fall City, WA 98024  
Mobile: 425.281.1471  
Email: [shawn@gravity.com](mailto:shawn@gravity.com)

Mr. Tim Thompson  
SEE LLC  
4401 Latona Ave NE  
Seattle WA, 98105  
Mobile: 206.418.6173  
Email: [tthompson@seellc.com](mailto:tthompson@seellc.com)

### 3.3 Quality Assurance/Quality Control

Amara Vandervort is the Windward QA/QC coordinator. In this capacity, she will oversee coordination of the field sampling and laboratory programs, and she will supervise data validation and project QA coordination, including coordination with the analytical laboratories and the EPA QA officer, Don Matheny. Ms. Vandervort will also maintain the official approved QAPP and coordinate the distribution of any updated versions of the QAPP to appropriate parties. Ms. Vandervort can be reached as follows:

Ms. Amara Vandervort  
Windward Environmental LLC  
200 West Mercer Street, Suite 401  
Seattle, WA 98119  
Telephone: 206.812.5415  
Email: [amarav@windwardenv.com](mailto:amarav@windwardenv.com)

Mr. Matheny can be reached as follows:

Mr. Don Matheny  
US Environmental Protection Agency, Region 10  
1200 6<sup>th</sup> Avenue  
Seattle, WA 98101  
Telephone: 206.553.2599  
Email: [matheny.don@epa.gov](mailto:matheny.don@epa.gov)

John Laplante is the Anchor QEA QA/QC coordinator for engineering PDI data collection and management. In this capacity, he will oversee coordination of the engineering data collection programs. Mr. Laplante can be reached as follows:

Mr. John Laplante  
Anchor QEA LLC  
1201 3<sup>rd</sup> Avenue, Suite 2600  
Seattle, WA 98101  
Telephone: 206.903.3323  
E-mail: [jlaplante@anchorqea.com](mailto:jlaplante@anchorqea.com)

Independent third-party chemical data review and validation will be provided by Laboratory Data Consultants, Inc. (LDC). The PM at LDC can be reached as follows:

Ms. Pei Geng  
Laboratory Data Consultants, Inc.  
2701 Loker Ave. West, Suite 220  
Carlsbad, CA 92010

760.827.1100 (ext. 141)

Email: [pgeng@lab-data.com](mailto:pgeng@lab-data.com)

### 3.4 Laboratory Responsibilities

Amara Vandervort of Windward is the laboratory coordinator for the analytical chemistry and toxicity testing laboratories. Matt Woltman of Anchor QEA is the geotechnical laboratory coordinator for geotechnical testing. Analytical Resources, Inc. (ARI) will perform all chemical analyses on the sediment samples, with the exception of analyses for dioxins/furans. SGS Axys Analytical Services Ltd. (SGS Axys) will perform analyses for dioxins/furans. Vista Analytical Laboratory (Vista) and OnSite Environmental Inc. (OnSite) will serve as backup laboratories. EcoAnalysts, Inc. (EcoAnalysts) will perform the toxicity testing. Geotechnical testing will be performed by Harold L Benny & Associates, LLC (Harold Benny).

The laboratory PM at ARI can be reached as follows:

Ms. Susan Dunnihoo  
Analytical Resources, Inc.  
4611 South 134<sup>th</sup> Place  
Tukwila, WA 98168-3240  
Telephone: 206.695.6207  
Email: [limsadm@arilabs.com](mailto:limsadm@arilabs.com)

The laboratory PM at SGS Axys can be reached as follows:

Ms. Georgina Brooks  
SGS Axys Analytical Services Ltd.  
2045 West Mills Road  
Sidney, British Columbia V8L 5X2  
Canada  
Telephone: 250.655.5801  
Email: [Georgina.Brooks@sgs.com](mailto:Georgina.Brooks@sgs.com)

The laboratory PM at Vista can be reached as follows:

Ms. Martha Maier  
Vista Analytical Laboratory  
1104 Windfield Way  
El Dorado Hills, CA 95762  
Telephone: 916.673.1520  
Email: [mmaier@vista-analytical.com](mailto:mmaier@vista-analytical.com)

The laboratory PM at OnSite can be reached as follows:

David Baumeister  
OnSite Environmental Inc.  
14648 NE 95<sup>th</sup> Street  
Redmond, WA 98052  
Telephone: 425.883.3881  
Email: [baumeister@onsite-env.com](mailto:baumeister@onsite-env.com)

The laboratory PM at EcoAnalysts can be reached as follows:

Mr. Jay Word  
EcoAnalysts, Inc.  
4729 NE View Drive  
PO Box 216  
Port Gamble, WA 98364  
Telephone: 206.779.9500  
Email: [jword@ecoanalysts.com](mailto:jword@ecoanalysts.com)

The geotechnical laboratory PM at Harold Benny can be reached as follows:

Mr. Harold Benny  
Harold L Benny & Associates, LLC  
18027 10<sup>th</sup> Place NE  
Poulsbo, WA 98370  
Telephone: 360.979.9250  
Email: [haroldlbenny@gmail.com](mailto:haroldlbenny@gmail.com)

The laboratories will meet the following requirements:

- Adhere to the methods outlined in this QAPP, including those methods referenced for each procedure.
- Adhere to documentation, custody, and sample logbook procedures.
- Implement QA/QC procedures defined in this QAPP.
- Meet all reporting requirements.
- Deliver electronic data files as specified in this QAPP.
- Meet turnaround times for deliverables as described in this QAPP.
- Allow EPA and the QA/QC manager, or a representative, to perform laboratory and data audits.

### 3.5 Data Management

Kim Goffman of Windward will oversee all environmental and geotechnical data management and will confirm that analytical data are incorporated into the LDW database with appropriate qualifiers following acceptance of the data validation. QA/QC of the database entries will provide accuracy for use in the pre-design studies. Ms. Goffman can be reached as follows:

Ms. Kim Goffman  
Windward Environmental LLC  
200 West Mercer Street, Suite 401  
Seattle, WA 98119  
Telephone: 206.812.5414  
Email: [kimg@windwardenv.com](mailto:kimg@windwardenv.com)

### 3.6 Special Training/Certification

The Superfund Amendments and Reauthorization Act of 1986 required the Secretary of Labor to issue regulations through the Occupational Safety and Health Administration (OSHA) providing health and safety standards and guidelines for workers engaged in hazardous waste operations. Accordingly, 29 Code of Federal Regulations (CFR) 1910.120 requires that employees be given the training necessary to provide them with the knowledge and skills to enable them to perform their jobs safely and with minimum risk to their personal health. All sampling personnel will have completed the 40-hour HAZWOPER training and 8-hour refresher courses, as necessary, to meet OSHA regulations. The FC/HSO will also have completed the eight-hour HAZWOPER supervisor training.

Also, all analytical laboratories have current environmental laboratory accreditation from the Washington State Department of Ecology (Ecology) and other accreditation agencies for the analytical methods to be used. Geotechnical laboratories are not accredited; Harold Benny is a qualified geotechnical laboratory that has 20 years' experience conducting American Society for Testing and Materials (ASTM) procedures for geotechnical testing.

### 3.7 Documentation and Records

All field activities and laboratory analyses will be documented following the protocols described in this section. In addition, data reduction rules and data report formats are provided herein.

#### 3.7.1 Field Observations

All field activities will be recorded in a field logbook maintained by the FC or designee. The field logbook will provide a description of all sampling activities, conferences between the FC and EPA oversight personnel associated with field sampling activities, sampling personnel, and weather conditions, as well as a record of all modifications to the procedures and plans identified in this QAPP and the HSP (Appendix C). The field logbook will consist of bound,

numbered pages, and all entries will be made in indelible ink. Photographs, taken with a digital camera, will provide additional documentation of the surface sediment collection activities and all bank sampling areas. The field logbook is intended to provide sufficient data and observations to enable participants to reconstruct events that occurred during the sampling period.

The following field forms, included as Appendix D, will also be used to record pertinent information after sample collection:

- Surface sediment collection form
- Sediment core collection form
- Bank sample collection form
- Shoreline visual inspection form
- Structures visual inspection form
- Soil boring form
- Vane shear form
- Dynamic cone penetrometer (DCP) log
- DCP field form
- Protocol modification form
- Chain of custody form

Information regarding equipment calibration and other sampling activities will be documented in the field logbook.

### *3.7.2 Laboratory Records*

#### **3.7.2.1 Chemistry Records**

The analytical laboratories will be responsible for internal checks on sample handling and analytical data reporting and will correct errors identified during the QA review. The laboratory data packages will be submitted electronically and will include the following, as applicable:

- **Project narrative:** This summary, in the form of a cover letter, will present any problems encountered during any aspect of sample analyses. The summary will include, but not be limited to, discussion of QC, sample shipment, sample storage, and analytical difficulties. Any problems encountered by the laboratory will be documented, as will their resolutions. In addition, operating conditions for instruments used for the analysis of each suite of analytes and definitions of laboratory qualifiers will be provided.
- **Records:** Legible copies of the chain of custody forms will be provided as part of the data package. This documentation will include the time of receipt and the condition of each

sample received by the laboratory. Additional internal tracking of sample custody by the laboratory will also be documented.

- **Sample results:** The data package will summarize the results for each sample analyzed.

The summary will include the following information, as applicable:

- Field sample identification (ID) code and the corresponding laboratory ID code
- Sample matrix
- Date of sample extraction/digestion
- Date and time of analysis
- Weight used for analysis
- Final dilution volumes or concentration factor for the sample
- Percent solids in the samples
- Identification of the instruments used for analysis
- Method detection limits (MDLs)<sup>5</sup> and RLs<sup>6</sup>
- All data qualifiers and their definitions

- **QA/QC summaries:** These summaries will contain the results of all QA/QC procedures.

Each QA/QC sample analysis will be documented with the same information required for the sample results (see above). The laboratory will make no recovery or blank corrections, except for isotope dilution method correction prescribed by EPA. The required summaries will include the following information, as applicable:

- The calibration data summary will contain the concentrations of the initial calibration and daily calibration standards and the date and time of analysis. The response factor, percent relative standard deviation (%RSD), relative percent difference (RPD), and retention time for each analyte will be listed, as appropriate. Results for standards analyzed to indicate instrument sensitivity will be reported.
- The internal standard area summary will report the internal standard areas, as appropriate.
- The method blank analysis summary will report the method blank analysis associated with each sample and the concentrations of all compounds of interest identified in these blanks.
- The surrogate spike recovery summary will report all surrogate spike recovery data for organic analyses. The names and concentrations of all compounds added, percent recoveries, and QC limits will be listed.

---

<sup>5</sup> The term MDL includes other types of DLs, such as estimated detection limit (EDL) values calculated for dioxin/furan congeners.

<sup>6</sup> RL values are consistent with the lower limit of quantitation (LLOQ) values required under EPA-846.

- The labeled compound recovery summary will report all labeled compound recovery data for EPA method 1613b. The names and concentrations of all compounds added, percent recovery, and QC limits will be listed.
- The matrix spike (MS) recovery summary will report the MS or MS/matrix spike duplicate (MSD) recovery data for analyses, as appropriate. The names and concentrations of all compounds added, percent recoveries, and QC limits will be included. The RPD for all MS and MSD analyses will be reported.
- The matrix duplicate summary will report the RPD for all matrix duplicate analyses. The QC limits for each compound or analyte will be listed.
- The certified reference material (CRM) analysis<sup>7</sup> summary will report the results of the CRM analyses and compare these results with published concentration ranges for the CRMs.
- The LCS analysis summary will report the results of the analyses of LCSs. The QC limits for each compound or analyte will be included.
- The relative retention time summary will report the relative retention times for the primary and confirmational columns of each analyte detected in the samples and the percent difference between the columns, as appropriate.
- The ion abundance ratio summary for samples analyzed by EPA method 1613b will report computed ion abundance ratios compared to theoretical ratios listed in the applicable method.
- **Original data:** Legible copies of the original data generated by the laboratory will be provided, including the following:
  - Sample extraction/digestion, preparation, and cleanup logs
  - Instrument specifications and analysis logs for all instruments used on days of calibration and analysis
  - Reconstructed ion chromatograms for all samples, standards, blanks, calibrations, spikes, replicates, LCSs, and CRMs
  - Enhanced and unenhanced spectra of target compounds detected in field samples and method blanks, with associated best-match spectra and background-subtracted spectra, for all gas chromatography/mass spectrometry (GC/MS) analyses
  - Enhanced and unenhanced spectra of target performance reference compounds (PRCs) detected in field samples, day-zero blanks, field blanks, and method

---

<sup>7</sup> CRMs will be analyzed for polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyl (PCB) Aroclors, and dioxins/furans. All other analyses will include a laboratory control sample (LCS). Specific information is listed in Section 4.10.

- blanks, with associated best-match spectra and background-subtracted spectra, for all GC/MS analyses
- Quantitation reports for each instrument used, including reports for all samples, blanks, calibrations, MSs/MSDs, laboratory replicates, LCSs, and CRMs

The analytical laboratories will submit data electronically, in EarthSoft EQuIS® standard four-file or EZ\_EDD format. Guidelines for electronic data deliverables for chemical data are provided on the EarthSoft website, <http://www.earthsoft.com/en/index.html>, and additional information will be communicated to the analytical laboratories by the project QA/QC coordinator or data manager. All electronic data submittals must be tab-delimited text files with all results, MDLs (as applicable), and RLs reported to the appropriate number of significant figures. If laboratory replicate analyses are conducted on a single submitted field sample, the laboratory sample identifier must distinguish among the replicate analyses.

### 3.7.2.2 Toxicity Testing Records

The bioassay laboratory, EcoAnalysts, will be responsible for internal checks on sample handling and toxicity test data reporting and will correct errors identified during the QA review. The laboratory data packages will be submitted electronically and will include the following, as applicable:

- **Project narrative:** This summary, in the form of a cover letter, will present any problems encountered during any aspect of sample analyses. The summary will include, but not be limited to, summary of test methods, discussion of QC, sample shipment, sample storage, and analytical difficulties. Any problems encountered by the laboratory will be documented, as will their resolutions. In addition, definitions of laboratory qualifiers will be provided.
- **Records:** Legible copies of the chain of custody forms will be provided as part of the data package. This documentation will include the time of receipt and the condition of each sample received by the laboratory. Additional internal tracking of sample custody by the laboratory will also be documented.
- **Sample results:** The data package will summarize the bioassay results and replicate data for each sample analyzed. The summary will include the following information, as applicable:
  - Field sample ID code and the corresponding laboratory ID code
  - Toxicity test and test species
  - Bioassay start and end date and time
  - Weight of a representative subsample of organisms at the start of sediment exposures

- Test acceptability requirements and discussion of any deviations from these requirements
- **QA/QC summaries:** These summaries will contain the results of all QA/QC checks, including the following as applicable:
  - Serial dilutions
  - LCS and reference toxicant tests
  - Any additional QC procedures required by applicable method protocols and laboratory SOPs
- **Original data:** Legible copies of the original data generated by the laboratory will be provided, including the following:
  - Source of control sediment and associated measurements
  - Water quality monitoring results
  - Measured light intensity during testing
  - Laboratory worksheets

EcoAnalysts will submit data electronically, in a Microsoft™ Excel spreadsheet format to be provided by Windward.

### 3.7.2.3 Geotechnical Testing Records

The geotechnical laboratory, Harold Benny, will be responsible for internal checks on sample handling and geotechnical data reporting. The laboratory data packages will be submitted as an electronic report and will include the following, as applicable:

- **Project narrative:** This summary, in the form of a cover letter, will present any problems encountered during any aspect of geotechnical testing. The summary will include, but not be limited to, summary of test methods, discussion of QC, sample shipment, sample storage, and testing difficulties as applicable. Any problems encountered by the laboratory will be documented, as will their resolutions.
- **Records:** Legible copies of the chain of custody forms will be provided as part of the data package. This documentation will include the time of receipt and the condition of each geotechnical sample received by the laboratory.
- **Sample results:** The geotechnical data report will summarize the geotechnical testing results for each sample analyzed. The summary will include the following information, as applicable:
  - Field sample ID code and the corresponding laboratory ID code
  - Geotechnical data for each type of testing performed
  - Test acceptability requirements and discussion of any deviations from these requirements

- **Original data:** Legible copies of the original data generated by the laboratory will be provided.

Harold Benny will submit data electronically, in PDF report and Excel format, where applicable.

### *3.7.3 Data Reduction*

Data reduction is the process by which original data (i.e., analytical measurements) are converted or reduced to a specified format or unit to facilitate analysis of the data. Data reduction requires that all aspects of sample preparation that could affect the test result, such as sample volume analyzed or dilutions required, be taken into account in the final result. It is the laboratory analyst's responsibility to reduce the data, which are subjected to further review and reduction by the laboratory PM, the Windward TM, the QA/QC coordinator, and independent reviewers. The data will be generated in a format amenable to review and evaluation. Data reduction may be performed manually or electronically. If performed electronically, all software used must be demonstrated to be true and free from unacceptable error.

### *3.7.4 Data Storage and Backup*

All electronic files related to the project will be stored on a secure server on Windward's network. The server contents are backed up on an hourly basis, and a copy of the backup is uploaded nightly to a secure off-site facility.

## 4 Data Generation and Acquisition for Sediment and Bank Analytical Samples

This section presents details of the PDI data generation and acquisition for sediment and bank analytical samples. This section also addresses how samples will be collected, processed, and analyzed, including QA/QC, instrument maintenance and calibration, and data management requirements. PDI sampling includes the following elements that involve sampling and analysis of sediment or bank samples to address DQOs 1 through 7, 9, 10, and 11:

- Sediment collection and analysis of 0- to 10-cm, 0- to 45-cm, 0- to 60-cm, and > 60-cm samples
- Toxicity testing of surface sediment samples (0 to 10 cm)
- Bank sample collection and analysis

Other PDI elements associated with engineering design elements are discussed in Section 5.

### 4.1 Sampling Design for Sediment and Bank Samples

This section discusses the sampling design for sediment and bank sampling, including approaches and rationale for tiering, depth intervals, analytes, sampling locations, toxicity testing, and phasing. The conceptual sediment sampling design for PDI sampling is discussed in the PDIWP and is summarized briefly herein (Windward and Anchor 2019).

#### 4.1.1 Tiered sample collection

The PDI sediment sampling design involves the collection of two tiers of samples:

- Tier 1 – Locations sampled for immediate analysis
- Tier 2 – Locations sampled for sample archival with analysis dependent on the results of Tier 1 analyses

Tier 1 and Tier 2 samples will be collected during the same sampling effort. Tiering will enable the collection of data in a more targeted and efficient manner, by focusing Tier 2 on questions identified in Tier 1.

#### 4.1.2 Sediment sample depth intervals

Data will be gathered at two depth intervals to delineate RAL exceedances (Table 4-1). In the intertidal area, most locations will be sampled at both the 0- to 10- and 0- to 45-cm intervals. In the subtidal areas, most locations will be sampled at both the 0- to 10- and 0- to 60-cm intervals. Two intervals may not be sampled at a given location if recent data already exist for one of the intervals; details are described in Section 4.1.4.

In federal navigation channel (FNC) areas with shoals (current elevations shallower than the authorized depth of -15 feet MLLW in this section of the LDW), the 0- to 10-cm interval will be sampled, and the 0- to 60-cm interval will be expanded as appropriate to include the shoal in the intervals analyzed (Figure 4-1). The subsurface sediment design sampling intervals will depend on the thickness of the shoal material. When the thickness of the shoal is less than 60 cm (i.e., the surface is deeper than -13 feet MLLW), one sample will be collected to -17 feet MLLW. When shoal material is greater than or equal to 60 cm thick (i.e., the surface is equal to or shallower than -13 feet MLLW), two samples will be collected to characterize sediment to -17 feet MLLW. One sample will characterize the sediment interval to -15 feet MLLW and the second sample will include sediment between -15 and -17 feet MLLW (Figure 4-1). In addition, to support FNC maintenance dredging, a 1-foot (30-cm) Z-sample will be collected and archived to characterize the interval from -17 to -18 feet MLLW. This interval represents the post-dredge sediment surface following maintenance dredging.

**Table 4-1**  
**Sample Depth Intervals for Phase I**

Sample Depth Intervals	Intertidal	Subtidal (outside FNC)	FNC Shallower than -15 feet MLLW		FNC Deeper than -15 feet MLLW
0–10 cm	X	X	X		X
0–45 cm	X	na	na		na
0–60 cm	na	X	na – replaced by shoal samples		X
Shoal samples to -17 feet MLLW	na	na	Shoal < 60 cm 1 sample	Shoal > 60 cm 2 samples <sup>1</sup>	na
Z-sample (-17 to -18 feet MLLW)	na	na	X		na <sup>2</sup>

Notes:

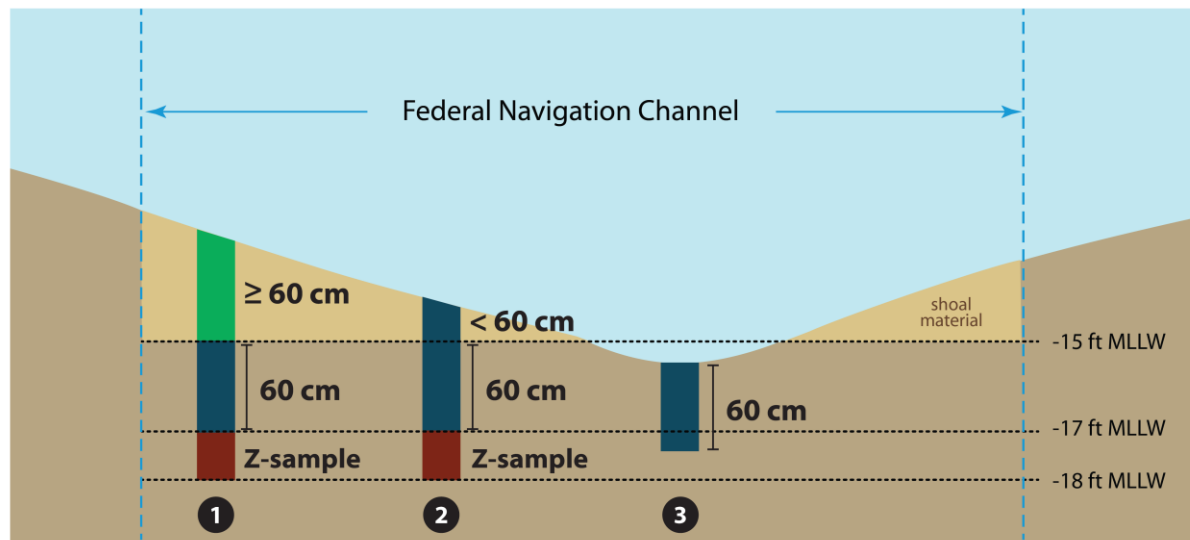
1. In locations where shoal thickness is greater than 60 cm, one sample will characterize sediment to -15 feet MLLW, and a second sample characterize -15 to -17 feet MLLW, as shown in Figure 4-1.
2. No Z-sample is required because the 0–60-cm sample will characterize sediment to depths greater than -17 feet MLLW.

FNC: federal navigation channel

MLLW: mean lower low water

na: not applicable

**Figure 4-1**  
**Federal Navigation Channel Design Sampling**



- 1 When thickness of shoal material is greater than or equal to 60 cm then the core will be taken to -18 ft MLLW and two samples will be collected; one sample will represent the shoal material and the other sample will represent material between -15 ft and -17 ft MLLW. A 1 ft Z-sample (-17 ft to -18ft MLLW) will be collected and archived. A 0-10 cm sample will also be collected (not shown).
- 2 When thickness of shoal material is less than 60 cm then the core will be taken to -18 ft MLLW and one sample will represent both the shoal material and the material between -15 ft and -17 ft MLLW. A 1 ft Z-sample (-17 ft to -18ft MLLW) will be collected and archived. A 0-10 cm sample will also be collected (not shown).
- 3 In the portions of the FNC that are not shoaled (deeper than -15ft MLLW) a 0-60 cm sample will be collected. A 0-10 cm sample will also be collected (not shown).

### 4.1.3 Analytes by Sample Type

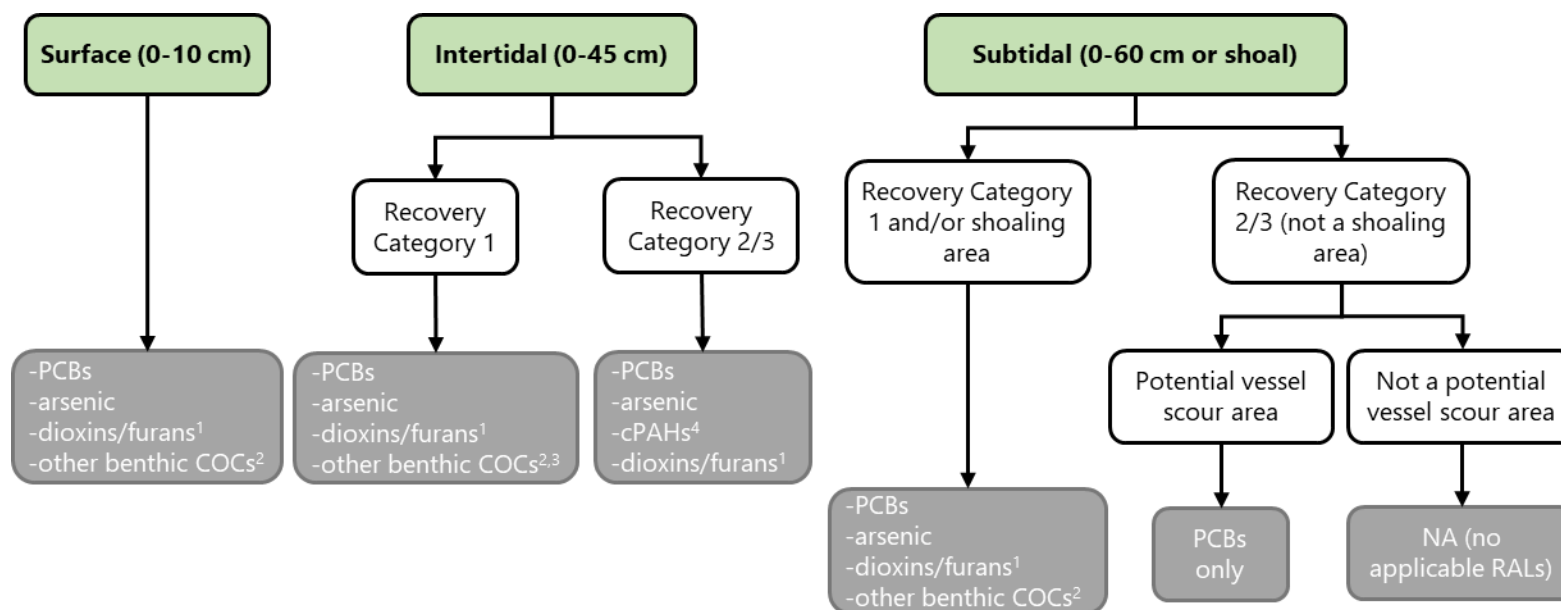
The analyte list for each Phase I sediment sample differs depending on which RALs are applicable. RAL applicability is determined based on the sample type (i.e., intertidal or subtidal), sample interval, recovery category, and other location-specific factors. RAL applicability is summarized in Figure 4-2 according to the RALs presented in ROD Tables 27 and 28 (EPA 2014b). Figure 4-2 assumes that an explanation of significant differences will be issued by EPA based on the updated benzo(a)pyrene toxicity value. This explanation of significant differences would result in a carcinogenic polycyclic aromatic hydrocarbon (cPAH) RAL only applicable in the 0- to 45-cm samples collected from intertidal beach play areas (see Appendix G of the Pre-Design Studies data evaluation report (Windward 2018)).<sup>8</sup>

In general, Tier 1 samples in Phase I will be analyzed for all contaminants of concern (COCs) with an applicable RAL for that sample, with the exception of dioxins/furans. Dioxins/furans will be analyzed in approximately 20% of Phase I Tier 1 samples, because existing data indicate that

<sup>8</sup> No change would be made to the benthic RALs for PAH compounds.

dioxins/furans are not generally expected to exceed the RAL in the upper reach (Windward and Anchor 2019); archive material will be available to analyze dioxins/furans for other locations, if needed. Specific locations for dioxin/furan analysis were selected as described in Section 4.1.4.2. The analyte list for Tier 2 (archive) samples will be determined in a meeting with EPA based on unvalidated Phase I data and other identified site-specific concerns, if any. The specific analytes to be analyzed for each sample are presented in Section 4.1.4.2.

**Figure 4-2**  
**Required analytes per ROD Table 27 and 28**



**Notes:**

An archive jar will be collected for all samples, provided sufficient volume is available.

1. A subset of samples will be analyzed for dioxins/furans.
2. Other benthic COCs are the 39 benthic risk drivers in ROD Table 27; while PCBs and arsenic are also benthic COCs, they are addressed by the lower human health RALs because they are also human health COCs.
3. cPAHs will be calculated for beach play areas using the PAH data collected in the 0- to 45-cm intervals in Recovery Category 1.
4. cPAHs will be analyzed only in 0- to 45-cm samples collected from beach play areas (based on the RAL update with the updated benzo(a)pyrene toxicity data).

#### 4.1.4 Phase I Sediment Sampling Design

To address DQOs 1 through 7, this section presents the general principles discussed in the PDIWP (Windward and Anchor 2019) and information from recent dredging used to identify specific sediment sampling locations. The resulting sediment sampling locations are shown on Maps 2 to 6.

##### 4.1.4.1 General Principles for Identification of Locations

To determine specific sediment sampling locations, the following three principles (i.e., reoccupation, bounding, and spatial coverage) were applied based on existing data for the upper reach, as discussed in Section 3.3 of the PDIWP (Windward and Anchor 2019):

- **Reoccupation** - Locations with RAL exceedances (or concentrations close to RAL exceedances) in remedial investigation/feasibility study (RI/FS) data were selected for reoccupation in design sampling. Locations were also selected for reoccupation if post-FS samples were collected prior to and near recent disturbances (e.g., near early actions). These samples will be analyzed in Tier 1. In addition to reoccupying existing locations, locations around the reoccupied locations were selected for collection of archive samples. Archive samples will be selected for Tier 2 analysis in consultation with EPA if RAL exceedances are detected in the Tier 1 reoccupied location samples or if needed for spatial coverage, depending on the Tier 1 results.
- **Bounding** – Sampling locations were selected to bound areas with more than one existing RAL exceedance and documented historical sources, recent (< 10 years old) data with RAL exceedances, and exceedance factors (EFs) greater than approximately 2.
- **Spatial coverage** – Additional locations were selected for spatial coverage if existing data were limited, particularly in the 0- to 45-cm or 0- to 60-cm intervals, and in areas where there is reason to believe RAL exceedances may exist. Specific locations were selected based on spatial coverage, the variability of existing data and a comparison of those data to the RAL, and the existence of and potential for nearby sources.

In addition to the general principles and information provided by existing data, recent dredge characterization results and/or frequent dredging were taken into account when determining the sediment sampling locations.

Dredge characterization sampling typically includes the collection of sediment from intervals greater than 60 cm, and samples are typically composites of multiple locations. Therefore, while the data are not appropriate for comparison to RALs, the data are indicative of sediment quality

within a given area. Areas where the design sampling has been informed by the results of dredge characterization or other investigations are summarized below.

- **FNC (RM 4.05 to Turning Basin)** – Based on the results of the 2018/2019 dredge characterization from RM 4.05 to RM 4.25, all sediment was suitable for open-water disposal (USACE et al. 2018a). The frequency of dredging in the FNC in this area is every 6 to 10 years from RM 4.05 to RM 4.25 and approximately every 2 years from RM 4.25 to the Turning Basin. Dredging the FNC from RM 4.05 to the Turning Basin takes two dredge seasons; a portion of this area was dredged in the 2018/2019 dredge season, and the remainder will be dredged in the 2019/2020 dredge season. All dredged material from the 2018/2019 season was suitable for open-water disposal (USACE et al. 2018a). Z-samples collected to characterize the post-dredge sediment in the upstream portion (RM 4.05 to RM 4.25) had dioxin/furan toxic equivalents (TEQs) between 3 and 11 ng/kg (i.e., below the lowest RAL of 25 ng/kg). To comply with Ecology’s anti-degradation regulations, 1 foot of shoal was left in place. Because of the frequency of dredging in this area and the fact that it will be newly dredged by the end of the current dredge season, no design sampling is needed.
- **South Park Marina** – The northern half of South Park Marina was last dredged in 1993 to an authorized depth of -8 feet MLLW with 1 foot of allowable overdredge. All dredged material was suitable for open-water disposal (USACE et al. 1991). Dioxin/furan analysis was not required as part of dredged material characterization in 1993. In addition to the dredge characterization, post-FS sampling for PCBs was conducted in 2016 in this area (including 20 surface sediment samples and 16 cores to 200 cm deep). None of the 0- to 10-cm or 10- to 100-cm sediment samples exceeded the PCB RALs for 0 to 10 cm and 0 to 60 cm sediments, respectively. Therefore, no design sampling is needed in the South Park Marina (Map 2; Segment 1), except in the southwest corner, where PCBs exceeded the RAL in multiple 0- to 10-cm samples collected between 2004 and 2011.
- **Duwamish Yacht Club** – The Duwamish Yacht Club basin (RM 4.05 to RM 4.15 west) was last dredged in 1999, and all dredged material was suitable for open-water disposal (USACE et al. 1999). A subsequent dredged material characterization study was conducted in 2012. The dioxin/furan TEQs in two out of six dredged material management units (DMMUs) (both of which were located in the southern end of the marina [Map 7]) were greater than the Dredged Material Management Program (DMMP) criterion of 10 ng/kg TEQ (no other chemicals were above the DMMP criteria). The DMMU composite that characterized the 0- to 4-feet sediment interval in the southern area (DMMU 4) had a dioxin/furan TEQ of 20.94 ng/kg (Map 7). The DMMU representing the 4- to 6-feet sediment interval in the southwestern corner of the marina (DMMU 6)

had a dioxin/furan TEQ of 10.74 ng/kg (USACE 2013). Dredging was not conducted following this characterization. In addition, a 0- to 10-cm near-outfall sediment sample collected in 2018 at RM 4.17 east (just upstream of the Duwamish Yacht Club) had a dioxin/furan TEQ of 21.7 ng/kg (below RAL of 25 ng/kg TEQ). Based on these data, no samples are needed in the northern portion of the Duwamish Yacht Club because the DMMUs in this area were suitable for open-water disposal, making RAL exceedances unlikely. In the southern part of the basin, design sampling will be conducted to determine if dioxin/furan TEQs are below the RAL (Map 4; Segment 3a).

- **Delta Marine** – Dredging was conducted at Delta Marine at RM 4.2 west between 2008 and 2010. The sediment was characterized in three DMMUs (Map 7). Dioxin/furans were analyzed in DMMUs 3 and 4 and the dioxin/furan TEQs for the dredged material and the Z-samples were all less than 4 ng/kg (USACE et al. 2007b). All dredged material characterized in three DMMUs, was suitable for open-water disposal (USACE et al. 2007a), no design sampling is needed in the Delta Marine area (Map 4; Segment 3a).

#### 4.1.4.2 Selected sampling locations

In addition to the 609 surface and 21 subsurface sampling locations in the existing RI/FS and post-FS datasets, a total of 223 sampling locations have been identified for Phase I sampling based on the above-described principles and dredge characterization information. Of these 222, 109 are Tier 1 locations, and 113 are Tier 2 locations (Table 4-2). The locations of each of the Phase I sampling locations, along with other relevant data, are shown on Maps 2 to 6. In addition, the rationale for the placement of each sampling location, the intervals collected at each location, and applicable analytes (as described in Figure 4-2 and Section 4.1.3) are presented in Table G-1 in Appendix G.

**Table 4-2**  
**Summary of Upper Reach Sampling Locations**

Segment	Count of RI/FS and Post-FS Dataset Locations (PCB-only Locations) <sup>1</sup>		PDI Sampling Locations						
			Total Count of Locations	Count of Analytical Locations (Tier 1)			Count of Archive Locations (Tier 2)		
	Surface (0–10 cm) <sup>2</sup>	Subsurface		Total	Intertidal <sup>3</sup>	Subtidal <sup>4</sup>	Total	Intertidal <sup>3</sup>	Subtidal <sup>4</sup>
Segment 1 (RM 3.0 to RM 3.5)	103 (39)	4 (3)	59	24	9	15	35	14	21
Segment 2 (RM 3.5 to RM 4.05)	169 (37)	10 (4)	66	36	15	21	30	10	20
Segment 3 (RM 4.05 to RM 4.75)	270 (56)	7 (3)	72	38	24	14	34	22	12
Segment 4 (RM 4.75 to RM 5.0)	67 (10)	0 (0)	25	11	10	1	14	8	6
<b>Total</b>	<b>609 (142)</b>	<b>21 (10)</b>	<b>222</b>	<b>109</b>	<b>58</b>	<b>51</b>	<b>113</b>	<b>54</b>	<b>59</b>

Notes:

1. List of analytes differs by location (i.e., not all samples were analyzed for all analytes). PCB-only locations are included in the total and noted in parentheses. No individual 0- to 45-cm locations were sampled as part of the RI/FS or post-FS sampling.
2. In addition to the surface sediment samples listed, 50 surface sediment samples (split samples from the AOC3 surface sediment samples) are currently being analyzed by Ecology and NOAA for PCB congeners, dioxins/furans, PAHs, TBT, arsenic, lead, and mercury. The locations of these 50 samples (12 in Segment 1, 11 in Segment 2, 24 in Segment 3, and 3 in Segment 4) are shown on Maps 2 to 6. Data for these samples are expected in early 2020.
3. Intertidal locations generally include 0–10-cm and/or 0–45-cm samples (see Appendix G).
4. Subtidal locations generally include 0–10-cm and/or 0–60-cm samples (see Appendix G). Sample depths for subsurface samples in shoaling areas will vary depending on the depth of the shoal at each location (see Figure 4-1).

AOC3: Third Amendment to the Administrative Order on Consent

Ecology: Washington State Department of Ecology

NOAA: National Oceanic and Atmospheric Administration

PAH: polycyclic aromatic hydrocarbon

PCB: polychlorinated biphenyl

PDI: pre-design investigation

RI/FS: remedial investigation/feasibility study

RM: river mile

TBT: tributyltin

Additional factors that affected the selection of sample intervals at each location include:

- When recent data at a given location and interval are available, the interval does not need to be sampled again. For example, locations with recent 0- to 10-cm data only require collection of the 0- to 45-cm or 0- to 60-cm interval sample in that area.
- The 2019 bathymetry showed that the South Park Marina and Duwamish Yacht Club are now shallower than -4 feet MLLW (intertidal depths), but to maintain the intended use, subtidal depths are needed. The sample intervals were selected to reflect the intended use rather than the current intertidal bathymetry.
- Intertidal areas that are inaccessible do not require 0- to 45-cm intervals for clamming and beach play uses.
- Targeted toxicity testing locations will be sampled in the 0- to 10-cm interval and deeper intervals may not be sampled, depending on spatial coverage in that area.

The specific factors that affected sampling intervals at each location are provided in notes in Table G-1 in Appendix G.

Approximately 20% of the Tier 1 locations (i.e., 22 of 110 locations) have been identified for dioxin/furan analysis (Map 8). The locations identified for dioxin/furan analysis were determined based on existing surface and subsurface sediment data, as well as consideration of the additional 50 surface sediment samples in the upper reach (split samples from the 2018 baseline sediment surface sediment samples) that are currently being analyzed by Ecology and the National Oceanic and Atmospheric Administration (NOAA) for dioxins/furans. The selected Tier 1 locations, plus the 50 locations being analyzed by Ecology/NOAA, provide good overall spatial coverage of dioxins/furans in the upper reach, including the one area with a dioxin/furan RAL exceedance factor of 0.9 (no RI/FS or post-FS samples in the upper reach have exceeded the RAL for dioxins/furans).

#### *4.1.5 Phases I and II Toxicity Testing Design*

To address DQOs 1 and 2, toxicity testing can be used to help delineate remediation area boundaries. If a sediment is not toxic at a location based on benthic toxicity tests, then the toxicity result will override the benthic RAL chemistry result<sup>9</sup> in areas without human health RAL exceedances. Where benthic toxicity testing is expected to occur, simultaneous collection of sediment for chemistry and toxicity testing is required; the chemical analyses will be expedited so that the toxicity test can be initiated within the holding times of the toxicity tests.

---

<sup>9</sup> Per the note to ROD Table 20.

In Phase I, select locations will be tested for toxicity.<sup>10</sup> In Phase II or III, additional toxicity testing may be conducted in areas where only benthic RAL exceedances exist in a given area sufficiently large to warrant further investigation<sup>11</sup> and lacking human health COC RAL exceedances. These locations will be identified in QAPP addenda.

#### 4.1.6 Phases II and III Sediment and Bank Sampling Design

A Phase II QAPP addendum will be prepared to address specific data needs based on the interpretation of the Phase I results in the Phase I data evaluation report. To address DQOs 10 and 12, Phase II surface and subsurface sediment samples will be collected to further refine the preliminary boundaries of remedial action areas and the depths of contamination in those areas identified for dredging or capping remedial technologies.

Where needed, sediment sampling will also occur in areas with over-water structures (DQO 9). In the upper reach, over-water structures are present at the locations identified in Table 4-3. All structures will be assessed for potential safety concerns in Phase I so that where needed in Phase II, sampling can be conducted.

**Table 4-3**  
**Identified Over-water Structures Outside of EAAs in the Upper Reach of the Lower Duwamish Waterway**

RM (side)	Structure Number	Structure Name	Description	Access Notes
3.3–3.4 (both)	57	South Park Bascule Bridge	Bascule bridge with wing walls on each side of the navigation channel; 24-in. diameter wing wall piles spaced every 5 feet.	High overhead clearance. General access restrictions in the vicinity of the bridge piers and the wing walls.
3.4 (west)	39	South Park Marina	Marina with timber floating docks and timber guide piles. The shoreline is an ecology block bulkhead.	General access restrictions for an operational marina.

<sup>10</sup> The approach for benzyl alcohol-only exceedances is being developed with EPA and Ecology. Additional detail will be presented in the draft final QAPP.

<sup>11</sup> Per EPA's responsiveness summary (EPA 2014a), "a single isolated exceedance of a benthic SCO will not trigger additional remedial action. Instead, it will trigger additional monitoring to determine the nature and extent of the contamination in that area. Additional remedial action may be warranted if, for example, monitoring indicates a cluster of three or more points with COC concentrations exceeding the benthic SCO."

**Table 4-3**  
**Identified Over-water Structures Outside of EAAs in the Upper Reach of the Lower Duwamish Waterway**

RM (side)	Structure Number	Structure Name	Description	Access Notes
3.7-4.0 (east)	65	Miscellaneous steel and timber bulkheads	At approximately RM 3.7, the bulkhead wall changes to a soldier pile wall with timber lagging. In vicinity of upstream corner at RM 3.8, the bulkhead switches to steel sheet pile with timber fender piles and construction walers. About 100 feet upstream of fishnet 45, the steel sheet pile bulkhead starts; it continues to where structure 41 starts. The upstream end of the sheet pile wall has three dolphins.	There are no in-water obstructions or access restrictions other than the noted bulkheads and dolphins.
4.0 (west)	40	McElroy George and Assoc. Inc.	Concrete finger pier with 18-in. piles spaced at 7-foot and 10-foot bents. Concrete superstructure; barges tied up with no access to pier.	General access restrictions for the finger pier with multiple moored barges.
4.1 (east)	41	Northwest Container Services	Dolphin berth with seven berthing dolphins (nine-timber-pile clusters) and a derelict access L-shaped pier. The pile tops are cut off just above the water line with no decking (some decking remains, but not in all spans).	The derelict access pier has tight pile spaces but the majority does not have decking.
4.1 (west)	42	Duwamish Yacht Club	Marina with covered moorage, timber guide piles, and concrete floats. The marina has four separate docks accessed from four gangways. A timber travelift pier is located along the shoreline between the two southern docks.	The extent of the marina is close to the shoreline on three sides, restricting access of large equipment. The covered moorage will limit access below the floats.
4.2 (west)	43	Delta Marine Industries Wharf	Parallel finger piers for a boat lift, concrete pile cap, and concrete deck. Downstream of finger piers is a floating dock with steel guide piles (access limited due to mega yachts moored at the float).	General access restrictions around the floating docks and finger piers.
4.3 (east)	44	The Boeing Company Seattle Wharf	Six concrete loading piers exist along south shoreline of Slip 6, along with concrete deck and caps and octagonal pre-stressed piles. Pier pile cap spacing is ~20 feet on center. Timber fender piles exist along front face of piers. Between piers is a narrow, pile-supported apron structure with concrete deck, caps, and octagonal pre-stressed piles.	Low underdeck clearance will restrict access under the platforms.

**Table 4-3**  
**Identified Over-water Structures Outside of EAAs in the Upper Reach of the Lower Duwamish Waterway**

RM (side)	Structure Number	Structure Name	Description	Access Notes
4.7 (east)	66	Timber wharf and timber pile groins	Two timber pile-supported concrete wharfs exist along the shoreline (small platform downstream, larger platform upstream). Piles are at approximately 10- x 10-foot spacing with heavy cross bracing. Timber soldier pile bulkhead exists behind platform. Derelict timber groins extend from shore at a downstream angle.	Tight pile spacing and cross bracing will restrict access under the wharves. The timber groin piles form solid walls.

Notes:

Data on identified over-water structures were reported in *Waterway User Survey and Assessment of In-Water Structures – Data Report* (Integral et al. 2018).

EAA: early action area

FS: feasibility study

RM: river mile

To address DQO 11, bank samples will be collected where needed to delineate the extent of potential contamination in adjacent bank areas. The locations will be determined based on the preliminary boundaries of remedial technologies presented in the Phase I data evaluation report; the locations will be described in detail in the Phase II QAPP addendum. Topographical surveys will also be conducted in these areas, as needed.

## 4.2 Sediment Sampling Methods

This section provides methods to locate and collect surface and subsurface sediment samples as part of PDI sampling efforts. Detailed sediment sampling methods are included as SOPs in Appendix F.

### 4.2.1 Sediment Sampling Sequencing and Logistics

Phase I sediment sampling is anticipated to occur in late spring 2020.

Within each of the sample groups (i.e., Tier 1 and Tier 2), subsurface sediment samples (i.e., 0 to 45 cm, 0 to 60 cm, or deeper shoaling area cores) will be collected first to ensure that an acceptable core can be collected at a given location. The surface sediment samples (0 to 10 cm) will be collected next, using the coordinates from the actual core location as the target surface sample coordinates, unless the location is a reoccupation, in which case the surface sample will be collected at the original target coordinates.

For sampling locations that will be accessed via adjacent uplands or samples that will be collected from privately owned aquatic lands, access agreements with property owners that are not LDWG parties may be needed. All parties (including tenants of LDWG parties) will be notified well in advance of sampling to coordinate access. Notification will commence soon after the draft QAPP is submitted to EPA. In the event that LDWG or EPA cannot obtain access, alternative locations will be determined in consultation with EPA.

#### *4.2.2 Target Sampling Locations*

Target sampling locations are presented in Maps 2 to 6 and Table G-2 in Appendix G. For all sampling locations, the field crew will confirm the sampling area type (i.e., within or outside of the FNC and subtidal vs. intertidal) in real-time during sample collection.

For samples that are intended to reoccupy previous sampling locations, sample collection will be attempted as close as possible to the target coordinates and no further than 3 m (10 feet) from the target.

For samples that are not intended to reoccupy a previous sampling location, more flexibility is permitted. Sample collection first will be attempted within 3 m (10 feet) of the target coordinates. If this is not possible (e.g., due to an obstruction or because the location is too shallow to sample from a boat), the field crew will either move the sampling location (within a maximum distance of 10 m [32 feet]) or, in the case of shallow water, attempt to collect the sample on foot during a low tide. If the sampling location needs to be moved more than 10 m (32 feet), EPA and LDWG will be consulted. To minimize the need to move the sampling location, property owners with barges will be notified prior to the sampling event, and samples will be collected from shallow areas during higher tide levels during the field event. If the initial attempt to collect a sample is not successful due to difficult substrate (e.g., presence of riprap or other debris), up to three subsequent attempts will be made within 10 m (32 feet) of the proposed location. If the initial attempt and three subsequent attempts do not result in a sample that meets the appropriate acceptance criteria, a different sampling location may be selected in consultation with EPA and LDWG. Sampling locations planned to be positioned under known structures in Phase II will remain under structures if it is safe to sample in these locations.

#### *4.2.3 Surface Sediment Collection*

Surface sediment samples (0- to 10-cm) will be collected from a boat or from land. Based on the Phase I bank visual inspection, any locations that are determined to be inaccessible by boat or land may be deferred to Phase II for collection by a diver if safe to do so (Section 4.4). Surface sediment grab sample collection and processing will follow standardized procedures described in Ecology's Sediment Cleanup User's Manual II (SCUM II) (Ecology 2017). SOPs for the collection of surface sediment by boat and from land are presented in Appendix F.

The minimum sediment volume required for each chemistry sample (full analytical suite) is 36 oz; an additional 8 oz will be collected for archive if sufficient material is available (Section 4.10). For locations for which toxicity testing is planned, additional sample volume will be required (see Section 4.2.5.1). Following homogenization, sediment for chemistry analysis will be dispensed into one 4-oz, two 8-oz, and one 16-oz jars as appropriate.

#### ***4.2.4 Subsurface Sediment Collection***

Subsurface sediment core samples will be collected primarily using a vibracorer deployed from a sampling vessel. However, conditions may arise in the intertidal where sampling from a vessel is not possible; in these cases, the core must be manually collected from shore. The SOPs for collecting and processing intertidal (0 to 45 cm), subtidal (0 to 60 cm), and shoaling location sediment cores are presented in Appendix F. Based on the Phase I visual bank characterization, any locations that are determined to be inaccessible by boat or by foot may be deferred to Phase II for collection by a diver (Section 4.4).

#### ***4.2.5 Sediment Collection for Toxicity Testing***

##### **4.2.5.1 LDW Sediment**

For locations identified for toxicity testing, additional sediment will be collected during the collection of surface sediment grabs (Section 4.2.3). A total of 192 oz (6 L) of sediment will be collected at these locations. Thus, multiple grabs will be collected from the same location until sufficient volume has been obtained for both chemistry and toxicity testing samples. Sediment from all grabs will be thoroughly homogenized prior to distribution into the appropriate sample containers for both chemistry and toxicity testing. The sediment from locations identified for toxicity testing will be submitted for expedited analysis of all analytes in order to determine if the toxicity testing is required and to identify appropriate reference sediments. The expedited data will be available within two weeks of sample collection in order to initiate the bioassays within the holding time (56 days).

##### **4.2.5.2 Reference Area Sediment**

Reference area sediment will be collected by EcoAnalysts from locations in Carr Inlet such that the grain size and total organic carbon (TOC) are similar to that of the LDW samples being tested. In order to obtain a suitable reference sample and to best match the LDW samples, five locations will be sampled from the reference area following the reference area sediment sampling protocols in SCUM II (Ecology 2017) and the DMMP User Manual (USACE et al. 2018b). Field measurements of grain size will be used to inform the selection of the five samples.

At each reference area location, multiple grab samples will be combined and homogenized thoroughly to create a composite sample with sufficient volume for toxicity testing and analysis

of TOC, grain size, ammonia, and total sulfides. Additional sediment from the reference sites will be archived in case chemical analyses are needed at a later date.

In order to review reference area grain size and TOC data prior to initiating the bioassay testing, these analyses will be expedited. The grain size and TOC data for the five composite reference samples will be reviewed, and the toxicity test reference will be selected. The reference sediment percent fines should be within 20% of the test sediment percent fines and the TOC should be similar. If there is no single sample with TOC and grain size comparable to that of the LDW samples, then combining reference area samples to create a composite reference sample will be considered.

### 4.3 Bank Sampling Methods

Samples from bank areas, which are defined as the transition area from the LDW subtidal or intertidal bed to the upland areas above mean higher high water (MHHW) (Anchor and Windward 2019a), will be collected as part of Phase II sampling efforts. This section presents collection methods for both surface (0- to 10-cm) and subsurface bank samples. General areas for surface and subsurface sediment sampling will be identified in the QAPP addendum described in Section 4.1.6, following completion of Phase I visual bank inspections and evaluation of surface sediment sample data. Sampling and sample analysis may be tiered in Phase II (i.e., surface bank samples may be collected and analyzed prior to subsurface bank samples).

Each bank area adjacent to sediments identified for active remediation or monitored natural recovery to sediment cleanup objective (SCO) following evaluation of Phase I data will be characterized with new or existing data. Banks may be sampled at more than one elevation based on field and tidal conditions, substrate material, bank slope, and exposed bank area. The number of and depth of bank samples collected will be determined during the field effort based on these considerations, with coordination and input from EPA and Ecology.

Where surface bank samples are needed for design, they will be collected and processed in Phase II using methods similar to those described for surface sediment collection by hand in Appendix F. Methods for the collection of subsurface bank samples will vary depending on the condition of the bank, presence/absence of armoring, sampling location access, and elevation of the sampling location. Subsurface sample collection methods will involve vibracoring, drilling, or collection by hand (see SOPs in Appendix F, depending on the bank conditions. Bank-specific methods will be described in detail in the Phase II PDI QAPP Addendum. Analytes and total volume needed for each chemistry sample will be identified in the QAPP addendum.

### 4.4 Diver-related Activities

Based on the field conditions, any sediment sampling locations that are determined to be inaccessible by boat or foot may be collected during Phase II by a diver. In the event that divers

are required, the dive team will provide an HSP specific to diver-related activities. The Phase II QAPP addendum will present the sample collection methods to be used by the divers.

## 4.5 Sample Identification

Unique alphanumeric IDs will be assigned to each sample and recorded on the collection and processing forms (Appendix D-1).

The sample IDs for individual sediment samples will include the following:

- Project area ID (i.e., LDW) and two-digit year (i.e., 20 for Phase I samples)
- Sample type:
  - SS – surface sediment (0 to 10 cm)
  - IT – intertidal sediment (0 to 45 cm)
  - SC – subsurface core (depths variable)
  - BNKS – surface bank sample (0 to 10 cm)
  - BNKD – subsurface bank sample collected at depth (depths variable)
  - G – geotechnical sample
- Location number (see Table G-2 in Appendix G)
- For all subsurface cores (SC) and subsurface bank samples (BNKD), a sequential letter (e.g., A, B, etc.) will be used to identify the interval. The letter A will be used to indicate the targeted surface interval, with B, C, etc. used to indicate each subsequent interval. The letter Z will be used in the sample ID for all Z-samples, instead of A, B, C, etc.

For example, a surface sediment sample from location 127 would be labeled LDW20-SS127. The subtidal sediment core samples from that location would be labeled LDW20-SC127A for the first core interval (e.g., the 0 to 60 cm sample) and LDW20-SC127B for the next core interval sample (if applicable). The Z-sample at this location would be LDW20-SC127Z. Geotechnical boring location 1 would be designated LDW20-G1A for the first interval.

Any field duplicate sample collected will have the same sample ID as its parent sample but will be appended with “-FD” to identify it as a field duplicate.

## 4.6 Sample Custody and Shipping Requirements

Sample custody is a critical aspect of environmental investigations. Sample possession and handling must be traceable from the time of sample collection, through laboratory and data analyses, to delivery of the sample results to the recipient. Procedures to be followed for sample custody and shipping are detailed in this section.

### *4.6.1 Sample Custody Procedures*

Samples are considered to be in custody if they are: 1) in the custodian's possession or view; 2) in a secured place (under lock) with restricted access; or 3) in a container and secured with an official seal(s) such that the sample cannot be reached without breaking the seal(s). Custody procedures, described below, will be used for all samples throughout the collection, transportation, and analytical processes, and for all data and data documentation, whether in hard copy or electronic format. Custody procedures will be initiated during sample collection.

A chain of custody form will accompany all samples to the analytical laboratory. Each person who has custody of the samples will sign the chain of custody form and ensure that the samples are not left unattended unless properly secured. Minimum documentation of sample handling and custody will include:

- Sampling location, project name, and unique sample ID
- Sample collection date and time
- Any special notations on sample characteristics or problems
- Name of the person who initially collected the sample
- Date sample was sent to the laboratory
- Shipping company name and waybill number

In the field, the FC or a designee will be responsible for all sample tracking and custody procedures. The FC will also be responsible for final sample inventory and will maintain sample custody documentation. The FC or a designee will complete chain of custody forms prior to transporting samples. At the end of each day, and prior to sample transfer, chain of custody entries will be made for all samples. Information on the sample labels will be checked against sample log entries, and sample tracking forms and samples will be recounted. Chain of custody forms, which will accompany all samples, will be signed at each point of transfer. Copies of all chain of custody forms will be retained and included as appendices to the data reports. Samples will be shipped in sealed coolers.

The analytical laboratories will ensure that chain of custody forms are properly signed upon receipt of the samples and will note any questions or observations concerning sample integrity on the chain of custody forms. The analytical laboratories will contact the FC and project QA/QC coordinator immediately if discrepancies are discovered between the chain of custody forms and the sample shipment upon receipt.

### *4.6.2 Shipping Requirements*

Sediment and bank chemistry samples will be transported directly to ARI (i.e., by field staff) and will be shipped or transported via courier to SGS Axys and EcoAnalysts. Geotechnical samples will be transported directly (or shipped) to Harold Benny. Prior to shipping, containers with

sediment samples will be wrapped in bubble wrap and securely packed inside a cooler with ice packs. The original signed chain of custody forms will be placed in a sealed plastic bag and taped to the inside lid of the cooler. Fiber tape will be wrapped completely around the cooler. On each side of the cooler, a *This Side Up* arrow label will be attached; a *Handle with Care* label will be attached to the top of the cooler, and the cooler will be sealed with a custody seal in two locations.

The temperature inside the cooler(s) containing the sediment samples will be checked by the laboratory upon receipt of the samples. The laboratory will specifically note any coolers that do not contain ice packs, or that are not sufficiently cold<sup>12</sup> ( $\leq 4 \pm 2^{\circ}\text{C}$ ) upon receipt. All samples will be handled so as to prevent contamination or sample loss. Any remaining sediment samples will be disposed upon receipt of written notification by the Windward PM. Holding times will vary by analysis and are summarized in Section 4.9.2.

## 4.7 Decontamination Procedures

Sampling requires strict measures to prevent contamination. Sources of extraneous contamination can include sampling gear, grease from ship winches or cables, spilled engine fuel (gasoline or diesel), engine exhaust, dust, ice chests, and ice used for cooling. All potential sources of contamination in the field will be identified by the FC, and appropriate steps will be taken to minimize or eliminate contamination. For example, during retrieval of sampling gear, the boat will be positioned, when feasible, so that engine exhaust does not fall on the deck. Ice chests will be scrubbed clean with Alconox<sup>®</sup> detergent and rinsed with distilled water after use to prevent potential cross contamination. To avoid contamination from melting ice, the wet ice will be placed in separate plastic bags.

All sediment sampling and homogenizing equipment, including the mixing bowl and stainless steel implements, will be decontaminated between sampling locations per Ecology guidelines (2017) and the following procedures:

1. Rinse with site water and wash with a scrub brush until free of sediment.
2. Wash with phosphate-free detergent.
3. Rinse with site water.
4. Rinse with distilled water.

Acid or solvent washes will not be used in the field because of safety considerations and problems associated with rinsate disposal and sample integrity, specifically:

- Use of acids or organic solvents may pose a safety hazard to the field crew.

---

<sup>12</sup> As stated in validation guidance documents, sample shipping coolers should arrive at the laboratory with an internal temperature within the range of  $4 \pm 2^{\circ}\text{C}$ ; however, due to the short transit distance and time from the site to ARI, all samples may not have reached this temperature by the time they arrive at the laboratory.

- Disposal and spillage of acids and solvents during field activities pose an environmental concern.
- Residues of solvents and acids on sampling equipment may affect sample integrity for chemical testing.

Any sampling equipment that cannot be cleaned to the satisfaction of the FC will not be used for further sampling activities.

## 4.8 Field-generated Waste Disposal

Excess sediment, generated equipment rinsates, and decontamination water<sup>13</sup> will be returned to each sampling location after sampling has been completed for that location. All disposable sampling materials and personal protective equipment (PPE) used in sample processing, such as disposable coveralls, gloves, and paper towels, will be placed in heavyweight garbage bags or other appropriate containers. Disposable supplies will be removed from the site by sampling personnel and placed in a normal refuse container for disposal as solid waste.

## 4.9 Laboratory Methods for Sediment and Bank Samples

At each laboratory, a unique sample identifier (termed either project ID or laboratory ID) will be assigned to each sample. The laboratory will ensure that a sample tracking record follows each sample through all stages of laboratory processing. The sample tracking record must contain, at a minimum, the name/initials of individuals responsible for performing the analyses, dates of sample extraction/preparation and analysis, and types of analyses being performed.

The analytical laboratories will meet the sample handling requirements and follow the procedures described in this section. In addition, analytical methods and data quality indicator (DQI) criteria are provided herein. Laboratory methods for geotechnical testing are discussed in Section 5.3.3.2.

### 4.9.1 Laboratory Sample Handling

Samples will be stored initially at ARI at  $\leq 4 \pm 2^{\circ}\text{C}$ . Samples for the other laboratories will be packed in coolers on ice and delivered via courier service or shipped in coolers on ice. Bioassay sediments will be stored, refrigerated, after nitrogen purging of the headspaces in the jar at ARI. Archive samples will be stored, frozen, at ARI. The analytical laboratories will preserve and store samples as described in Section 4.9.2. Samples will be disposed after hold times expire, following written authorization from the Windward PM.

---

<sup>13</sup> Because decontamination water is an Alconox®/water solution (i.e., phosphate-free), it can be returned to the sampling location for disposal.

#### *4.9.2 Analytical Methods*

The analyte list for each Phase I sediment sample is summarized in Table G-1 in Appendix G by sample type. Chemical analysis of the sediment and bank samples will be conducted by two different laboratories (ARI and SGS Axys), and toxicity testing will be conducted by EcoAnalysts (Table 4-4). Analytical methods, toxicity test methods, and laboratory sample handling requirements for all measurement parameters are presented in Table 4-5. Geotechnical testing methods are presented in Section 5.3.3.2.

**Table 4-4****Sediment and Bank Analyses to be Conducted at each Analytical Laboratory**

<b>Laboratory</b>	<b>Analyses to be Conducted</b>	<b>Individual Analytes</b>
ARI	conventionals	TOC, percent solids, grain size, <sup>1</sup> ammonia, and sulfides
	metals	arsenic, cadmium, chromium, copper, lead, silver, zinc, mercury
	PAHs	acenaphthene, acenaphthylene, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(j)fluoranthene, benzo(k)fluoranthene, benzo(g,h,i)perylene, chrysene, dibenzo(a,h)anthracene, fluoranthene, fluorene, indeno(1,2,3-cd)pyrene, 2-methylnaphthalene, naphthalene, phenanthrene, and pyrene
	PCB Aroclors	Aroclor 1016, Aroclor 1221, Aroclor 1232, Aroclor 1242, Aroclor 1248, Aroclor 1254, Aroclor 1260
	SVOCs	1,2-dichlorobenzene, 1,2,4-trichlorobenzene, 1,4-dichlorobenzene, 2,4-dimethylphenol, 4-methylphenol, benzoic acid, benzyl alcohol, bis(2-ethylhexyl)phthalate, butyl benzyl phthalate, dibenzofuran, dimethyl phthalate, hexachlorobenzene, n-nitrosodiphenylamine, pentachlorophenol, and phenol
SGS Axys <sup>2</sup>	dioxin/furan congeners	2,3,7,8-TCDD, 1,2,3,7,8-PeCDD, 1,2,3,4,7,8-HxCDD, 1,2,3,6,7,8-HxCDD, 1,2,3,7,8,9-HxCDD, 1,2,3,4,6,7,8-HpCDD, OCDD, 2,3,7,8-TCDF, 1,2,3,7,8-PeCDF, 2,3,4,7,8-PeCDF, 1,2,3,4,7,8-HxCDF, 1,2,3,6,7,8-HxCDF, 1,2,3,7,8,9-HxCDF, 2,3,4,6,7,8-HxCDF, 1,2,3,4,6,7,8-HpCDF, 1,2,3,4,7,8,9-HpCDF, and OCDF
EcoAnalysts	toxicity testing	acute amphipod 10-day mortality test, acute 48-hr bivalve larvae combined mortality and abnormality test, and chronic 20-day juvenile polychaete survival and growth test

## Notes:

1. OnSite environmental will serve as the back-up laboratory for grain size analysis. All project QA/QC and reporting requirements listed for these analyses will be met by OnSite.
2. Vista will serve as the backup laboratory for dioxins/furans analysis. All project QA/QC and reporting requirements listed for these analyses will be met by Vista.

ARI: Analytical Resources, Inc.

EcoAnalysts: EcoAnalysts, Inc.

HpCDD: heptachlorodibenzo-*p*-dioxin

HpCDF: heptachlorodibenzofuran

HxCDD: hexachlorodibenzo-*p*-dioxin

HxCDF: hexachlorodibenzofuran

OCDD: octachlorodibenzo-*p*-dioxin

OCDF: octachlorodibenzofuran

PAH: polycyclic aromatic hydrocarbon

PCB: polychlorinated biphenyl

PeCDD: pentachlorodibenzo-*p*-dioxin

PeCDF: pentachlorodibenzofuran

QA/QC: quality assurance/quality control

SGS Axys: SGS Axys Analytical Services Ltd.

SVOC: semivolatile organic compound  
TCDD: tetrachlorodibenzo-*p*-dioxin  
TCDF: tetrachlorodibenzofuran  
TOC: total organic carbon  
Vista: Vista Analytical Laboratory

**Table 4-5****Analytical Methods and Sample Handling Requirements for Sediment and Bank Samples**

Parameter <sup>1</sup>	Method	Reference	Extraction Solvent	Cleanup	Laboratory	Container	Preservative	Sample Holding Time
<b>Chemistry</b>								
TOC	high-temperature combustion	EPA 9060A	na	na	ARI	8-oz Glass jar	cool to $\leq 4 \pm 2^{\circ}\text{C}$	28 days
Percent solids	drying oven	SM 2540G	na	na	ARI		cool to $\leq 4 \pm 2^{\circ}\text{C}$	6 months
Metals	ICP-MS	EPA 3050B EPA 6020A UCT-KED	na	na	ARI		cool to $\leq 4 \pm 2^{\circ}\text{C}$	6 months
Mercury	CV-AFS	EPA 7471B	na	na	ARI		freeze to $\leq -10^{\circ}\text{C}$	28 days
Grain size	Pipette/sieve	PSEP (1986)	na	na	ARI	16-oz Plastic jar	cool to $\leq 4 \pm 2^{\circ}\text{C}$	6 months
PAHs/SVOCs	GC/MS	EPA 3546/ EPA 8270E	DCM/acetone	Silica gel	ARI	8-oz Glass jar	freeze to $\leq -10^{\circ}\text{C}$	1 year to extraction if frozen; 14 days to extraction if refrigerated; when thawed, 40 days after extraction; store extracts at $\leq 6^{\circ}\text{C}$ and in the dark
SVOCs <sup>2</sup>	GC/MS	EPA 3546/ EPA 8270E-SIM	DCM/acetone	GPC (optional)	ARI		freeze to $\leq -10^{\circ}\text{C}$	1 year to extraction if frozen; 14 days to extraction if refrigerated; when thawed, 40 days after extraction; store extracts at $\leq 6^{\circ}\text{C}$ and in the dark

**Table 4-5****Analytical Methods and Sample Handling Requirements for Sediment and Bank Samples**

Parameter <sup>1</sup>	Method	Reference	Extraction Solvent	Cleanup	Laboratory	Container	Preservative	Sample Holding Time
PCB Aroclors	GC/ECD	EPA 3546 Mod EPA 8082A	hexane/acetone	Silica gel, sulfuric acid/permanganate sulfur, or acid/base partition (optional)	ARI		freeze to $\leq -10^{\circ}\text{C}$	1 year to extraction if frozen; 14 days to extraction if refrigerated; when thawed, 40 days after extraction; store extracts at $\leq 6^{\circ}\text{C}$ and in the dark
Hexachlorobenzene	GC/ECD	EPA 3546/EPA 8081B	Hexane/acetone	Silica gel, sulfur removal, GPC (optional)	ARI		freeze to $\leq -10^{\circ}\text{C}$	1 year to extraction if frozen; 14 days to extraction if refrigerated; when thawed, 40 days after extraction; store extracts at $\leq 6^{\circ}\text{C}$ and in the dark
Ammonia <sup>3</sup>	Flow injection	SM 4500-NH3 H-97	na	na	ARI	4-oz glass jar	cool to $\leq 4 \pm 2^{\circ}\text{C}$	7 days
Total sulfides <sup>3</sup>	Colorimetric	SM 4500-S2 D-0 PSEP prep	na	na	ARI	4-oz glass jar	2 mL 2 Normal zinc acetate; cool/0 to $6^{\circ}\text{C}$	7 days
Dioxins/furans	HRGC/HRMS	EPA 1613b	80:20 toluene: acetone or Dean-Stark with toluene	Biobead multi-layered acid/base silica, florisil, alumina, carbon/celite	SGS Axys	4-oz glass jar	freeze to $\leq -10^{\circ}\text{C}$	1 year until extraction and 1 year after extraction if stored in the dark at $\leq -10^{\circ}\text{C}$

**Table 4-5****Analytical Methods and Sample Handling Requirements for Sediment and Bank Samples**

Parameter <sup>1</sup>	Method	Reference	Extraction Solvent	Cleanup	Laboratory	Container	Preservative	Sample Holding Time
<b>Toxicity Testing</b>								
Amphipod and polychaete toxicity testing	na	PSEP 1995/ Ecology 2017	na	na	EcoAnalysts	32-oz HDPE wide-mouth jars	cool to $\leq 4 \pm 2^{\circ}\text{C}$ nitrogen purge of headspace	56 days until test initiation
Bivalve larvae toxicity testing	na	PSEP 1995/ Ecology 2017	na	na	EcoAnalysts	32-oz HDPE wide-mouth jar	cool to $\leq 4 \pm 2^{\circ}\text{C}$ nitrogen purge of headspace	56 days until test initiation

## Notes:

- Individual analytes are listed in Table 4-4.
- Analytes analyzed by 8270E-SIM include 2,4-dimethylphenol, benzoic acid, benzyl alcohol, n-Nitrosodiphenylamine, pentachlorophenol, 1,2,4-trichlorobenzene, 1,2-dichlorobenzene, and 1,4-dichlorobenzene.
- Ammonia and total sulfide analyses will only be conducted on the sediment locations targeted for possible toxicity testing.

ARI: Analytical Resources, Inc.

CV-AFS: cold vapor-atomic fluorescence spectroscopy

DCM: dichloromethane

DMMP: Dredged Material Management Program

EcoAnalysts: EcoAnalysts, Inc.

EPA: US Environmental Protection Agency

GC/ECD: gas chromatography/electron capture detection

GC/MS: gas chromatography/mass spectrometry

GPC: gel permeation chromatography

HDPE: high-density polyethylene

HRGC/HRMS: high-resolution gas chromatography/high-resolution mass spectrometry

ICP-MS: inductively coupled plasma-mass spectrometry

na: not applicable or not available

PAH: polycyclic aromatic hydrocarbon

PCB: polychlorinated biphenyl

PSEP: Puget Sound Estuary Program

SGS Axys: SGS Axys Analytical Services Ltd.

SIM: selected ion monitoring

SM: Standard Methods

SVOC: semivolatile organic compound

TOC: total organic carbon

UCT-KED: universal cell technology-kinetic energy discrimination

## 4.10 Sediment Chemistry Analytical Data Quality Objective and Criteria

The analytical DQO for sediment and bank samples is to develop and implement procedures that will ensure the collection of representative data of known, acceptable, and defensible quality. Parameters used to assess data quality are precision, accuracy, representativeness, completeness, comparability, and sensitivity (PARCCS). These parameters are discussed below, and specific DQIs are presented in Section 4.12.2.

Precision is the measure of reproducibility among individual measurements of the same property, usually under similar conditions, such as multiple measurements of the same sample. Precision is assessed by performing multiple analyses on a sample; it is expressed as an RPD when duplicate analyses are performed, and as a %RSD when more than two analyses are performed on the same sample (e.g., triplicates). Precision is assessed by laboratory duplicate analyses (e.g., duplicate samples, MSDs, and LCS duplicates) for all parameters. Precision measurements can be affected by the nearness of a chemical concentration to the DL, whereby the percent error (expressed as either %RSD or RPD) increases. The DQI for precision varies depending on the analyte. The equations used to express precision are as follows:

$$RPD = \frac{(\text{measured conc} - \text{measured duplicate conc})}{(\text{measured conc} + \text{measured duplicate conc}) \div 2} \times 100 \quad \text{Equation 1a}$$

$$\%RSD = (SD/D_{ave}) \times 100$$

Where:

$$SD = \sqrt{\left( \frac{\sum (D_n - D_{ave})^2}{(n-1)} \right)} \quad \text{Equation 1b}$$

D = sample concentration

D<sub>ave</sub> = average sample concentration

n = number of samples

SD = standard deviation

Accuracy is an expression of the degree to which a measured or computed value represents the true value. Accuracy may be expressed as a percentage recovery for MS, LCS, or CRM analyses. The DQI for accuracy varies depending on the analyte. The equation used to express accuracy for spiked samples is as follows:

$$\% \text{ Recovery} = \frac{\text{spike sample results} - \text{unspiked sample results}}{\text{amount of spike added}} \times 100 \quad \text{Equation 2}$$

Representativeness is an expression of the degree to which data accurately and precisely represent an environmental condition. The sampling approach was designed to address the specific objectives described in Section 2.1. Assuming those objectives are met, the samples collected should be considered adequately representative of the environmental conditions they are intended to characterize.

Comparability is an expression of the confidence with which one dataset can be evaluated in relation to another dataset. Therefore, sample collection and chemical and physical testing will adhere to the most recent PSEP and SCUM II QA/QC procedures (PSEP 1997; Ecology 2017) and EPA and Standard Methods (SMs) analysis protocols.

Completeness is a measure of the amount of data that is determined to be valid in proportion to the amount of data collected. The equation used to calculate completeness is as follows:

$$\text{Completeness} = \frac{\text{number of valid measurements}}{\text{total number of data points planned}} \times 100 \quad \text{Equation 3}$$

The DQI for completeness for all components of this project is 90%. Data that have been qualified as estimated because the QC criteria were not met will be considered valid for the purpose of assessing completeness. Data that have been qualified as rejected will not be considered valid for the purpose of assessing completeness.

Analytical sensitivity is the minimum concentration of an analyte above which a data user can be reasonably confident that the analyte was reliably detected and quantified. For this study, the MDL<sup>14</sup> or the LLOQ will be used as the measure of sensitivity for each analyte.

Table 4-6 lists specific DQIs for laboratory analyses of sediment and bank samples.

**Table 4-6**  
**Data Quality Indicators for Laboratory Analyses**

Parameter <sup>1</sup>	Unit	Precision <sup>2</sup>	Accuracy <sup>2</sup>		Completeness
			CRM/LCS <sup>3</sup>	Spiked Samples	
TOC	%	± 20%	80-120%	na	90%
Percent solids	%	± 20%	na	na	90%
Grain size	%	± 20%	na	na	90%

<sup>14</sup> The term MDL includes other types of DLs, such as EDL values calculated for dioxin/furan congeners. Recent revisions to EPA SW846 methods no longer require the calculation of MDLs.

**Table 4-6**  
**Data Quality Indicators for Laboratory Analyses**

Parameter <sup>1</sup>	Unit	Precision <sup>2</sup>	Accuracy <sup>2</sup>		Completeness
			CRM/LCS <sup>3</sup>	Spiked Samples	
Metals	mg/kg dw	± 20%	80–120%	75–125%	90%
Mercury	mg/kg dw	± 20%	80–120%	75–125%	90%
PAHs	µg/kg dw	± 35%	30–160%	30–160%	90%
PCB Aroclors	µg/kg dw	± 35%	50–120%	50–120%	90%
SVOCs	µg/kg dw	± 35%	10–160%	10–160%	90%
Hexachlorobenzene	µg/kg dw	± 35%	50–120%	50–120%	90%
Ammonia	mg/kg dw	± 20%	90–110%	75–125%	90%
Total sulfides	mg/kg dw	± 20%	75–125%	75–125%	90%
Dioxins/furans	ng/kg dw	± 20%	70–130%/ 63–170%	13–328% <sup>4</sup>	90%

Notes:

1. Individual analytes are listed in Table 4-4.
2. Values listed are performance-based limits provided by ARI and SGS Axys. The percentages provided represent the recovery range for each parameter. Individual compound recoveries vary within the recovery range.
3. An LCS may be used to assess accuracy when CRM is unavailable. CRMs will be analyzed for PAHs, PCB Aroclors, and dioxins/furans only. The satisfactory acceptance limit for CRM recovery will include the uncertainty range around the CRM mean as well as the uncertainty of the method measurement.
4. Labelled compound percent recovery range.

ARI: Analytical Resources, Inc.

CRM: certified reference material

dw: dry weight

LCS: laboratory control sample

na: not applicable

PAH: polycyclic aromatic hydrocarbon

PCB: polychlorinated biphenyl

SGS Axys: SGS Axys Analytical Services Ltd.

SVOC: semivolatile organic compound

TOC: total organic carbon

The laboratory MDL and RL goals for each analytical method are compared to their respective minimum sediment RALs in Tables 4-7 and 4-8. All of the analytical methods are sufficiently sensitive. Bank samples will be analyzed using the same methods and will have the same RL goals.

**Table 4-7****RAO 1, 2, and 4 COCs and Associated RL Goals and RALs for Sediment Samples**

COC	Method	Unit	RL	RAL <sup>1</sup>
PCBs	EPA 8082A (Aroclors) <sup>2</sup>	µg/kg dw	4	240 <sup>2</sup>
Arsenic	EPA 6020A	mg/kg dw	0.500	28
cPAH	EPA 8270E	µg TEQ/kg dw	18.1 <sup>3</sup>	900 <sup>4</sup>
Dioxins/ furans	EPA 1613b	ng TEQ/kg dw	1.14 <sup>5</sup>	25

## Notes:

1. RAL is minimum value for COC listed in the ROD Table 28 (EPA 2014b).
2. The organic carbon-normalized RAL was converted for this table to dry weight values using 2% TOC based on average LDW TOC. The RAL is 12 mg/kg organic carbon; sample results will be compared to the RAL based on the sample-specific TOC value
3. The RL for the cPAH TEQ value was calculated using one-half the RL for each of the cPAH compounds and the appropriate TEF values (California EPA 2009). Individual compound RLs are listed in Appendix E.
4. The ROD RAL is based on a benzo(a)pyrene slope factor that has since been updated. The older value is listed herein to provide a conservative estimate of the required sensitivity for the cPAH analysis.
5. The RL for the dioxin/furan TEQ value is based on the laboratory minimum calibration level from SGS Axys; the dioxin/furan mammalian TEQ value was calculated using one-half the RL for each dioxin/furan compound and appropriate mammal TEF values (Van den Berg et al. 2006). Individual congener LOQs are listed in Appendix E.

COC: contaminant of concern

cPAH: carcinogenic polycyclic aromatic hydrocarbon

dw: dry weight

EPA: US Environmental Protection Agency

LDW: Lower Duwamish Waterway

na: not applicable

PCB: polychlorinated biphenyl

RAL: remedial action level

RAO: remedial action objective

RL: reporting limit

ROD: Record of Decision

SGS Axys: SGS Axys Analytical Services, Ltd.

TEF: toxic equivalency factor

TEQ: toxic equivalent

TOC: total organic carbon

**Table 4-8****RAO 3 COCs and Associated RL Goals and RALs for Individual 0–10-cm Sediment Samples**

COC	Method	RL	Lowest RAL (SCO)
<b>Metals (mg/kg dw)</b>			
Arsenic	EPA 6020A	0.2	57
Cadmium	EPA 6020A	0.1	5.1
Chromium	EPA 6020A	0.5	260
Copper	EPA 6020A	0.5	390
Lead	EPA 6020A	0.1	450
Silver	EPA 6020A	0.2	6.1
Zinc	EPA 6020A	4	410
Mercury	EPA 7471B	0.025	0.41
<b>PAHs and SVOCs (µg/kg dw)</b>			
Benzo(a)anthracene	EPA 8270E	20.0	2,200 <sup>1</sup>
Benzo(a)pyrene	EPA 8270E	20.0	1,980 <sup>1</sup>
Total benzofluoranthenes	EPA 8270E	40.0	4,600 <sup>1</sup>
Chrysene	EPA 8270E	20.0	2,200 <sup>1</sup>
Dibenzo(a,h)anthracene	EPA 8270E	20.0	240 <sup>1</sup>
Indeno(1,2,3-cd)pyrene	EPA 8270E	20.0	680 <sup>1</sup>
Anthracene	EPA 8270E	20.0	4,400 <sup>1</sup>
Acenaphthene	EPA 8270E	20.0	320 <sup>1</sup>
Acenaphthylene	EPA 8270E	20.0	1,320 <sup>1</sup>
Benzo(g,h,i)perylene	EPA 8270E	20.0	620 <sup>1</sup>
Fluoranthene	EPA 8270E	20.0	3,200 <sup>1</sup>
Fluorene	EPA 8270E	20.0	460 <sup>1</sup>
Naphthalene	EPA 8270E	20.0	1,980 <sup>1</sup>
Phenanthrene	EPA 8270E	20.0	2,000 <sup>1</sup>
Pyrene	EPA 8270E	20.0	20,000 <sup>1</sup>
Total HPAHs <sup>2</sup>	EPA 8270E	40.0	19,200 <sup>1</sup>
Total LPAHs <sup>3</sup>	EPA 8270E	20.0	7,400 <sup>1</sup>
2,4-dimethylphenol	EPA 8270E-SIM	20.0	29
2-methylnaphthalene	EPA 8270E	20.0	760 <sup>1</sup>
4-methylphenol	EPA 8270E	20.0	670
Benzoic acid	EPA 8270E-SIM	100	650
Benzyl alcohol	EPA 8270E-SIM	5.00	57
Bis(2-ethylhexyl)phthalate	EPA 8270E	50.0	940 <sup>1</sup>

**Table 4-8****RAO 3 COCs and Associated RL Goals and RALs for Individual 0–10-cm Sediment Samples**

COC	Method	RL	Lowest RAL (SCO)
Butyl benzyl phthalate	EPA 8270E	20.0	98 <sup>1</sup>
Dibenzofuran	EPA 8270E	20.0	300 <sup>1</sup>
Dimethyl phthalate	EPA 8270E	20.0	1,060 <sup>1</sup>
Hexachlorobenzene	EPA 8081B	0.5	7.6 <sup>1</sup>
n-Nitrosodiphenylamine	EPA 8270E-SIM	5	220 <sup>1</sup>
Pentachlorophenol	EPA 8270E-SIM	20.0	360
Phenol	EPA 8270E	20.0	420
1,2,4-trichlorobenzene	EPA 8270E-SIM	5.00	16.2 <sup>1</sup>
1,2-dichlorobenzene	EPA 8270E-SIM	5.00	46.0 <sup>1</sup>
1,4-dichlorobenzene	EPA 8270E-SIM	5.00	62.0 <sup>1</sup>
<b>PCBs (µg/kg dw)</b>			
PCBs	EPA 8082A (Aroclors)	4	240 <sup>1</sup>

## Notes:

- Organic carbon-normalized RAL was converted to dry weight value for this table using 2% TOC (average LDW sediment TOC). This value, which is below the dry weight AETs in Table 8-1 of SCUM II (Ecology 2017), is presented herein as a dry weight value only for the purpose of comparison to RLs.
- HPAH compounds include fluoranthene, pyrene, benzo(a)anthracene, chrysene, total benzofluoranthenes, BaP, indeno(1,2,3 cd)pyrene, dibenzo(a,h)anthracene, and benzo(g,h,i)perylene.
- LPAH compounds include naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, and 2-methylnaphthalene.

AET: apparent effects threshold

COC: contaminant of concern

dw: dry weight

EPA: US Environmental Protection Agency

HPAH: high-molecular-weight polycyclic aromatic hydrocarbon

LDW: Lower Duwamish Waterway

LOQ: limit of quantification

LPAH: low-molecular-weight polycyclic aromatic hydrocarbon

PAH: polycyclic aromatic hydrocarbon

PCB: polychlorinated biphenyl

RAL: remedial action level

RAO: remedial action objective

RL: reporting limit

ROD: Record of Decision

SCO: sediment cleanup objective

SCUM II: Sediment Cleanup User's Manual II

SGS Axys: SGS Axys Analytical Services, Ltd.

SIM: selective ion monitoring

SMS: Washington State Sediment Management Standards

SVOC: semivolatile organic compound

TOC: total organic carbon

WAC: Washington Administrative Code

Standard mass requirements are specified to meet RL goals for each particular analytical method. Table 4-9 summarizes the sample volume needed for each sample type. The masses listed include those required for QC samples.

**Table 4-9**  
**Sample Mass Required per Analysis**

Analyte	Sediment Mass (ww)	Container Size
<b>Chemistry samples</b>		
TOC	6 g	8-oz jar
Percent solids	45 g	
Metals	3 g	
Mercury	1 g	
Grain size	600 g	16-oz jar
PAHs	60 g	8-oz jar
PCB Aroclors	75 g	
Hexachlorobenzene	75 g	
SVOCs	60 g	
Ammonia <sup>1</sup>	25 g	4-oz jar
Total sulfides <sup>1</sup>	25 g	4-oz jar
Dioxins/furan congeners	40 g	4-oz jar
Archive	na	8-oz jar
All chemical analyses	965 g	44 oz
<b>Toxicity samples</b>		
Toxicity testing	2,400 g	6 32-oz jars

Notes:

1. Ammonia and total sulfide samples will be collected only at the sediment locations targeted for possible toxicity testing.

PAH: polycyclic aromatic hydrocarbon

PCB: polychlorinated biphenyl

SVOC: semivolatile organic compound

TOC: total organic carbon

ww: wet weight

## 4.11 Sediment Chemistry Quality Assurance/Quality Control

The types of samples analyzed and the procedures conducted for QA/QC in the field and laboratory are described in this section.

Before analyzing the samples, the laboratory must provide written protocols for the analytical methods to be used, calculate RLs for each analyte in each matrix of interest as applicable, and establish an initial calibration curve for all analytes. The laboratory must also demonstrate its continued proficiency by participation in inter-laboratory comparison studies, and by repeated

analysis of certified reference materials (CRMs), calibration checks, laboratory reagent and rinsate blanks, and spiked samples.

#### **4.11.1      *Sample Delivery Group***

Project- and/or method-specific QC measures, such as MSs and MSDs or laboratory duplicates, will be used per sample delivery group (SDG) preparatory batch or per analytical batch, as specified in Table 4-10. An SDG is defined as no more than 20 samples or a group of samples received at the laboratory within a 2-week period. Although an SDG may span two weeks, all holding times specific to each analytical method will be met for each sample in the SDG.

**Table 4-10**  
**Laboratory Quality Control Sample Analysis Summary**

Analysis Type	Initial Calibration	Initial Calibration Verification (2 <sup>nd</sup> source)	Continuing Calibration Verification	CRM or LCS <sup>1</sup>	Laboratory Replicates	MS	MSD	Method Blanks	Surrogate Spikes
TOC	Prior to analysis	After initial calibration	Every 10 samples	1 per 20 samples or per batch	1 per 20 samples or per batch	1 per 20 samples or per batch	na	1 per 20 samples or per batch	na
Percent solids	na	na	na	na	1 per 20 samples or per batch	na	na	na	na
Grain size	na	na	na	na	Triplicate per 20 samples	na	na	na	na
Metals	Prior to analysis	After initial calibration	Every 10 samples	1 per prep batch	1 per batch or SDG	1 per batch or SDG	na	1 per prep batch	na
Mercury	Prior to analysis	After initial calibration	Every 10 samples	1 per prep batch	1 per batch or SDG	1 per batch or SDG	na	1 per prep batch	na
PAHs	Prior to analysis	After initial calibration	Every 12 hours	1 per prep batch <sup>2</sup>	na	1 per batch or SDG	1 per batch or SDG	1 per prep batch	Each sample
PCB Aroclors	Prior to analysis	After initial calibration	Every 10–20 analyses or 12 hours	1 per prep batch <sup>3</sup>	na	1 per batch or SDG	1 per batch or SDG	1 per prep batch	Each sample
Hexachlorobenzene <sup>4</sup>	Prior to analysis	After initial calibration	Every 10–20 analyses or 12 hours	1 per prep batch	na	1 per batch or SDG	1 per batch or SDG	1 per prep batch	Each sample
SVOCs	Prior to analysis	After initial calibration	Every 12 hours	1 per prep batch	na	1 per batch or SDG	1 per batch or SDG	1 per prep batch	Each sample
Ammonia	Prior to analysis	After initial calibration	Every 10 samples	1 per prep batch	1 per batch or SDG	1 per batch or SDG	na	1 per prep batch	na
Total sulfides	Prior to analysis	After initial calibration	Every 10 samples	1 per prep batch	1 per prep batch or SDG	1 per batch or SDG	na	1 per prep batch	na
Dioxins/furans	Prior to analysis	After initial calibration	Every 12 hours	1 per prep batch <sup>3</sup>	1 per prep batch	na	na	1 per prep batch	Each sample

Notes:

A batch is a group of samples of the same matrix analyzed or prepared at the same time, not exceeding 20 samples.

1. An LCS may be used to assess accuracy when CRM is unavailable.
2. CRM142-50G, 172-100G or 143 BNAs -Sandy Loam will be used to assess accuracy for PAHs.
3. Puget Sound sediment reference material will be used to assess accuracy for PCB Aroclors and dioxins/furans.
4. Hexachlorobenzene will be analyzed separately from the other SVOCs following EPA method 8081B.

CRM: certified reference material

EPA: US Environmental Protection Agency LCS: laboratory control sample

MS: matrix spike

MSD: matrix spike duplicate

na: not applicable or not available

PAH: polycyclic aromatic hydrocarbon

PCB: polychlorinated biphenyl

SDG: sample delivery group

SVOC: semivolatile organic compound

TOC: total organic carbon

#### **4.11.2 Laboratory Quality Control Samples**

The analyst will review the results of QC analyses from each sample group immediately after a sample group has been analyzed. The QC sample results will then be evaluated to determine whether control limits have been exceeded.

If control limits have been exceeded, then appropriate corrective action, such as recalibration followed by reprocessing of the affected samples, must be initiated before a subsequent group of samples is processed. The project QA/QC coordinator must be contacted immediately by the laboratory PM if satisfactory corrective action to achieve the DQIs outlined in this QAPP is not possible. All laboratory corrective action reports relevant to the analysis of project samples must be included in the data deliverable packages.

All primary chemical standards and standard solutions used in this project will be traceable to the National Institute of Standards and Technology, Environmental Resource Associates, National Research Council of Canada, or other documented, reliable, commercial sources. Standards will be validated to determine their accuracy by comparing them to independent standards. Laboratory QC standards are verified in a multitude of ways: Second-source calibration verifications (i.e., same standard, two different vendors) are analyzed to verify initial calibrations; new working standard mixes (e.g., calibrations, spikes, etc.) are verified against the results of the original solution and must be within 10% of the true value; newly purchased standards are verified against current data. Any impurities found in the standard will be documented.

The following sections summarize the procedures that will be used to assess data quality throughout sample analysis. Table 4-10 summarizes the QC procedures to be performed by the laboratory. The associated control limits for precision and accuracy are listed in Table 4-6.

##### **4.11.2.1 Method Blanks**

Method blanks are analyzed to assess possible laboratory contamination at all stages of sample preparation and analysis. A minimum of 1 method blank will be analyzed for each SDG or for every 20 samples, whichever is more frequent.

##### **4.11.2.2 Certified Reference Material**

CRMs are samples of similar matrices and known analyte concentrations, processed through the entire analytical procedure and used as an indicator of method accuracy. A minimum of 1 CRM will be analyzed for each SDG or for every 20 samples, whichever is more frequent. CRMs will be analyzed for PAHs, PCB Aroclors, and dioxins/furans. An LCS sample can be used to assess accuracy if appropriate CRM is not available. An LCS will be analyzed for conventional, metals, and semivolatile organic compound (SVOC) analyses.

#### **4.11.2.3 Laboratory Control Samples**

LCSs are prepared from a clean matrix using the same process as the project samples that are spiked with known amounts of the target compounds. The recoveries of the compounds are used as a measure of the accuracy of the test methods.

#### **4.11.2.4 Laboratory Replicate Samples**

Laboratory replicate samples provide information on the precision of the analysis and are useful in assessing potential sample heterogeneity and matrix effects. Laboratory replicates are subsamples of the original sample that are prepared and analyzed as separate samples, assuming sufficient sample matrix is available. A minimum of 1 laboratory replicate sample will be analyzed for each SDG or for every 20 samples, whichever is more frequent, for metals, conventional parameters, and dioxins/furans.

#### **4.11.2.5 Matrix Spikes and Matrix Spike Duplicates**

The analysis of MS samples provides information on the extraction efficiency of the method on the sample matrix. By performing MSD analyses, information on the precision of the method is also provided for organic analyses. For organic analyses, a minimum of 1 MS/MSD pair will be analyzed for each SDG or for every 20 samples, whichever is more frequent, when sufficient sample volume is available, with the exception of dioxins/furans. For inorganic analyses (i.e., metals), a minimum of one MS sample will be analyzed for each SDG, when sufficient sample volume is available.

#### **4.11.2.6 Surrogate Spikes**

All project samples analyzed for organic compounds will be spiked with appropriate surrogate compounds, as defined in the analytical methods. Surrogate recoveries will be reported by the analytical laboratories; however, no sample results will be corrected for recovery using these values.

#### **4.11.2.7 Isotope Dilution Quantitation**

All project samples analyzed for dioxin/furan congeners will be spiked with a known amount of surrogate compounds, as defined in the analytical methods. The labeled surrogate compounds will respond similarly to the effects of extraction, concentration, and gas chromatography. Data will be corrected for the recovery of the surrogates used for quantification.

#### **4.11.2.8 Internal Standard Spikes**

Internal standards may be used for calibrating and quantifying organic compounds and metals using MSs. If internal standards are required by the method, all calibration, QC, and project samples will be spiked with the same concentration of the selected internal standard(s). Internal standard recoveries and retention times must be within method and/or laboratory criteria.

## 4.12 Sediment Toxicity Testing Quality Objectives and Quality Assurance/Quality

### 4.12.1 Laboratory Sediment Handling

Sediment submitted for toxicity testing will be obtained from the same field homogenate as the sediment submitted for chemical analyses. The homogenized sediment will be placed into six I-Chem™ 32-oz high-density polyethylene (HDPE) wide-mouth jars with zero headspace. These samples will be refrigerated after nitrogen purging of the headspaces in the jars at ARI, after which they will be shipped to EcoAnalysts, as needed. The sediment samples will be stored in the dark at  $4 \pm 2^{\circ}\text{C}$ . The toxicity tests will be initiated within eight weeks of sample collection.

Three standard PSEP sediment toxicity tests will be conducted on each sample collected from the locations identified for toxicity testing. These tests are:

- Acute 10-day amphipod mortality test (*Rhepoxynius abronius*, *Ampelisca abdita*, or *Eohaustorius estuarius*)
- Acute 48-hr bivalve larvae combined mortality and abnormality test (*Mytilus galloprovincialis* or *Dendraster excentricus*)
- Chronic 20-day juvenile polychaete survival and growth test (*Neanthes arenaceodentata*)

Toxicity testing will be conducted according to *Recommended Guidelines for Conducting Laboratory Bioassays on Puget Sound Sediments* (PSEP 1995), consistent with the updated protocols in (Ecology 2017). The laboratory SOPs for the sediment toxicity tests are provided in Appendix F.

#### 4.12.1.1 Acute 10-day Amphipod Mortality Test

Short-term adverse effects of sediments will be evaluated by measuring the survival of adult amphipods. The appropriate test species will be selected based on sediment grain size data (Table 4-11). Amphipods will be exposed to LDW sediment and reference sediment from Carr Inlet for a 10-day period. The test will be performed according to the procedures and QA/QC performance standards described in (Ecology 2017) with survival as the primary endpoint.

**Table 4-11**  
**Sediment Conditions and Preferred Amphipod Test Species**

Sediment Condition	Grain Size	Preferred Amphipod Test Species
Coarse	<60% fines	<i>R. abronius</i>
Fine-grained	>60% fines	<i>A. Abdita</i> or <i>E. estuarius</i>
High clay	>20% clay	<i>A. Abdita</i>

Sediment Condition	Grain Size	Preferred Amphipod Test Species
Low salinity <sup>1</sup> and clay	<20% clay	<i>E. estuarius</i>

Notes:

1. Interstitial salinity below 25 ppt.

ppt: parts per thousand

#### 4.12.1.2 Acute 48-hr Bivalve Larvae Combined Mortality and Abnormality Test

The endpoint assessed in bivalve larvae after a 48-hr exposure period is normal survivorship, which is a combined assessment of mortality and abnormality. Larvae of *M. galloprovincialis* are the preferred test organisms for this study. If *M. galloprovincialis* in spawning condition are unavailable, the echinoderm *D. excentricus* will be used. Test protocols and QA/QC performance standards will be in accordance with guidance (Ecology 2017; USACE et al. 2018b).

#### 4.12.1.3 Chronic 20-day Juvenile Polychaete Survival and Growth

The juvenile polychaete sublethal bioassay is used to characterize the toxicity of marine sediments based on worm growth. The target initial worm weight for test organisms will be between 0.5 and 1.0 mg. Parameters measured after 20-day sediment exposure are survival and growth in juvenile polychaetes (*N. arenaceodentata*). The test will be performed according to the procedures described in PSEP protocols (1995) and Johns et al. (1990), as well as the most recent *N. arenaceodentata* protocol adjustments presented in the 2013 clarification paper regarding the use of ash-free dry weights (AFDWs) (DMMP 2013) and the QA/QC guidance provided by Ecology (2017).

### 4.12.2 Toxicity Test Evaluation Criteria

The results of the toxicity tests will be evaluated relative to the marine biological criteria in SCUM II (Ecology 2017). The evaluation criteria are provided in Table 4-12.

**Table 4-12**  
**SMS Marine Biological Criteria**

Toxicity Test	Test Endpoint	SCO/SQS	CSL
Amphipod	10-day mortality	Test mortality >25% and statistical difference between test mortality and reference mortality ( $p < 0.05$ )	Test mortality – reference mortality $\geq 30\%$ and statistical difference between test mortality and reference mortality ( $p < 0.05$ )

Toxicity Test	Test Endpoint	SCO/SQS	CSL
Larval	Bivalve or echinoderm abnormality/mortality	Test normal survivorship/reference normal survivorship < 0.85 and statistical difference between test and reference response ( $p < 0.10$ )	Test normal survivorship/reference normal survivorship < 0.70 and statistical difference between test and reference response ( $p < 0.10$ )
Polychaete	Neanthes 20-day growth	Test mean individual growth/reference mean individual growth < 0.70 and statistical difference between test response and reference response ( $p < 0.05$ )	Test mean individual growth/reference mean individual growth < 0.50 and statistical difference between test response and reference response ( $p < 0.05$ )

Notes:

CSL: cleanup screening level

SCO: sediment cleanup objective

SMS: Washington State Sediment Management Standards

SQS: sediment quality standards

### 4.12.3 Data Quality Indicators

DQIs for sediment toxicity tests (Table 4-13) are based on guidelines provided in Ecology (2017). Compliance with these indicators will be confirmed by EcoAnalysts and Windward.

**Table 4-13**  
**Data Quality Indicators for Sediment Toxicity Testing**

Toxicity Test	DQI
Acute 10-day amphipod mortality test with <i>R. abronius</i> , <i>E. estuarius</i> , and <i>A. abdita</i>	<ul style="list-style-type: none"> <li>• Mean mortality in the negative control is <math>\leq 10\%</math>.</li> <li>• Mean mortality in reference sediments is <math>\leq 25\%</math></li> <li>• All organisms in a test must be from the same source.</li> <li>• The mean of the daily test temperature must be within <math>\pm 1^\circ\text{C}</math> of <math>15^\circ\text{C}</math> (<math>20^\circ\text{C}</math> for <i>A. abdita</i>)</li> <li>• Test must be conducted under continuous light.</li> <li>• DO, pH, and salinity must be within the acceptable ranges established by the protocol.</li> <li>• All test chambers should be identical and should contain the same amount of sediment and overlying water.</li> <li>• The LC50 for a positive control test should be within the mean <math>\text{LC50} \pm 2</math> standard deviations of the control chart.</li> </ul>

**Table 4-13**  
**Data Quality Indicators for Sediment Toxicity Testing**

Toxicity Test	DQI
Acute 48-hr bivalve larvae combined mortality and abnormality test with <i>M. galloprovincialis</i>	<ul style="list-style-type: none"> <li>• Normal survivorship expressed as actual counts is <math>\geq 0.70</math> for the control sediment and <math>\geq 0.65</math> for the reference sediment.</li> <li>• All organisms in a test must be from the same source.</li> <li>• The mean of the daily test temperature must be within <math>\pm 1^{\circ}\text{C}</math> of <math>16^{\circ}\text{C}</math> (<math>15^{\circ}\text{C}</math> for echinoderm <i>D. excentricus</i>).</li> <li>• Test must be conducted under a light cycle of 14 hrs light to 10 hrs dark.</li> <li>• DO, pH, and salinity must be within the acceptable ranges established by the protocol.</li> <li>• All test chambers should be identical and should contain the same amount of sediment and overlying water.</li> <li>• The EC50 for a positive control test should be within the mean EC50 <math>\pm 2</math> standard deviations of the control chart.</li> </ul>
Chronic 20-day juvenile polychaete survival and growth test with <i>N. arenaceodentata</i>	<ul style="list-style-type: none"> <li>• Mean juvenile polychaete weight must be between 0.5 and 1.0 mg dw at test initiation.</li> <li>• Mean mortality in the negative control must be <math>\leq 10\%</math>.</li> <li>• Mean individual growth rate must be <math>\geq 0.38</math> mg/individual/day dw in the control.</li> <li>• Mean individual growth rate in reference sediment divided by mean individual growth rate in negative control must be <math>\geq 0.80</math> as AFDW.</li> <li>• All organisms in a test must be from the same source.</li> <li>• The mean of the daily test temperature must be within <math>\pm 1^{\circ}\text{C}</math> of <math>20^{\circ}\text{C}</math>.</li> <li>• Test must be conducted under continuous light.</li> <li>• DO, pH, and salinity must be within the acceptable ranges established by the protocol.</li> <li>• All test chambers should be identical and should contain the same amount of sediment and overlying water.</li> <li>• The EC50 for a positive control test should be within the mean EC50 <math>\pm 2</math> standard deviations of the control chart.</li> </ul>

Notes:

AFDW: ash-free dry weight

DO: dissolved oxygen

DQI: data quality indicator

dw: dry weight

EC50: concentration that causes a non-lethal effect in 50% of an exposed population

LC50: concentration that is lethal to 50% of an exposed population

QA/QC: quality assurance quality control

#### 4.12.4 Sediment Toxicity Testing Quality Control Criteria

All three sediment toxicity tests will incorporate standard QA/QC procedures to ensure that the test results are valid. Standard QA/QC procedures include the use of a negative control, a

positive control, and reference sediment samples, as well as the measurement of water quality during testing.

The negative control will be a test using a clean, inert material and the same diluent seawater used in testing sediment toxicity. For the amphipod and polychaete tests, the negative control will be native sediment from the organism collection site (Appendix F). For the polychaete test, the negative control will be sand collected from Yaquina Bay (*Eohaustorius* home sediment) or other clean amphipod control sediment. For the bivalve larvae test, the negative control seawater will be ambient seawater from North Hood Canal.

For the positive control, a reference toxicant will be used to establish the relative sensitivity of the test organism. The positive control for sediment tests is typically conducted with diluent seawater and without sediment. Reference toxicants are often used in positive controls. In addition to the positive controls with reference toxicants, positive controls using ammonia (water exposure only) will be performed.

Reference sediment will also be included with each toxicity test series. Reference sediments provide toxicity data that can be used to separate toxicant effects from unrelated effects, such as those of sediment grain size. Reference sediments are also used in statistical comparisons to determine whether test sediments are toxic. Sediment samples selected to be test reference sediment should represent the range of important natural, physical, and chemical characteristics of the test sediments, specifically sediment grain size and TOC. Sediments to be used as reference sediment for the three bioassays will be collected from Carr Inlet (PSEP 1995) (Section 4.2.5.2).

Bioassays require that proper water quality conditions be maintained to ensure that organisms survive and do not experience undue stress unrelated to test sediments. Salinity, dissolved oxygen (DO), pH, ammonia, total sulfides, and temperature will be regularly measured during testing. Temperature, salinity, DO, and pH will be measured daily for all three tests.

Interstitial porewater will be analyzed for ammonia and total sulfides at test initiation and termination for both the amphipod and polychaete tests. Ammonia and total sulfides will be measured in overlying water in all three tests at test initiation and test termination.

#### **4.13 Instrument/Equipment Testing, Inspection, and Maintenance**

Prior to each field event, measures will be taken to test, inspect, and maintain all field equipment. All equipment used, including the DGPS unit and digital camera, will be tested for accuracy before leaving for the field event.

The FC will be responsible for overseeing the testing, inspection, and maintenance of all field equipment. The laboratory PM will be responsible for ensuring laboratory equipment testing,

inspection, and maintenance requirements are met. The methods used in calibrating the analytical instrumentation are described in Section 4.14.

#### **4.14 Instrument/Equipment Calibration and Frequency**

Multipoint initial calibration will be performed on each analytical instrument at the start of the project, after each major interruption to the instrument, and when any continuing calibration does not meet the specified criteria. The number of points used in the initial calibration is defined in each analytical method. Continuing calibrations will be performed daily for organic analyses, every 10 samples for inorganic analyses, and with every sample batch for conventional parameters to ensure proper instrument performance.

Gel permeation chromatography (GPC) calibration verifications will be performed at least once every seven days, and corresponding raw data will be submitted by the laboratory with the data package. In addition, florasil performance checks will be performed for every florasil lot, and the resulting raw data will be submitted with the data package.

Calibration of analytical equipment used for chemical analyses includes the use of instrument blanks or continuing calibration blanks, which provide information on the stability of the baseline established. Continuing calibration blanks will be analyzed immediately after the continuing calibration verification, at a frequency of 1 blank for every 10 samples analyzed for inorganic analyses, and 1 blank every 12 hours for organic analyses. If the continuing calibration does not meet the specified criteria, the analysis must stop. Analysis may resume after corrective actions have been taken to meet the method specifications. All project samples analyzed by an instrument found to be out of compliance must be reanalyzed.

#### **4.15 Inspection/Acceptance of Supplies and Consumables**

The FC will gather and check field supplies daily for satisfactory conditions before each field event. Batteries used in the digital camera will be checked daily and recharged as necessary. Supplies and consumables for the field sampling effort will be inspected upon delivery and accepted if the condition of the supplies is satisfactory.

#### **4.16 Analytical Data Management**

All field data will be recorded on field forms, which the FC will check for missing information at the end of each field day and amend as necessary. A QC check will be done to ensure that all data have been transferred accurately from the field forms to the database. Field forms will be archived in the Windward library.

Analytical laboratories are required to submit data in an electronic format, as described in Section 3.7.2. The laboratory PM will contact the project QA/QC coordinator prior to data delivery to discuss specific format requirements.

A library of routines will be used to translate typical electronic output from laboratory analytical systems and to generate data analysis reports. The use of automated routines will ensure that all data are consistently converted to the desired data structures, and that operator time is kept to a minimum. In addition, routines and methods for quality checks will be used to ensure such translations are correctly applied.

Written documentation will be used to clarify how field and analytical laboratory duplicates and QA/QC samples were recorded in the data tables, and to provide explanations of other issues that may arise. The data management task will include keeping accurate records of field and laboratory QA/QC samples so that project team members who use the data will have appropriate documentation. All data management files will be secured on the Windward network. Data management procedures outlined in Appendix C of the Pre-Design Studies Work Plan will be followed (Windward and Integral 2017).

## 5 Data Generation and Acquisition of Engineering PDI Elements

This section discusses the study design and procedures for collecting, handling, and managing data that will be acquired in support of the engineering PDI elements. This section presents the methods for the following key elements:

- Bank visual inspection (DQO 8) and focused topographic surveys (DQO 11)
- Inspections and evaluations of existing structures within or adjacent to active remedial action areas to develop design criteria for remedial activities that may impact existing structures (DQO 14)
- Collection of geotechnical data for use in RD; assessing material behavior; and conducting stability modeling for banks, structures, and dredge or capping areas (DQO 13)
- Specialized surveys (e.g., utilities, debris characterization, sediment thickness overlying armoring in bank areas) as necessary to adequately characterize site conditions for engineering design and construction bid documents (DQO 14)

### 5.1 Banks

#### 5.1.1 Phase I Visual Inspection of Banks

To address DQO 8, a visual survey and inspection of shoreline conditions in bank areas located within the upper reach will be performed during the Phase I PDI to document overall bank conditions that will inform RD (i.e., presence/absence of bank armoring, evidence of significant erosion, presence of structures, presence of vegetation).

Bank areas may be armored or unarmored. The presence of armoring will be documented, as will the nature of any armoring (e.g., concrete blocks, mats, riprap, bulkheads) and its superficial condition. For unarmored banks, factors that may affect bank stability or indicate erosion will be noted, including: bank steepness, surface material type, observed bank undermining, and presence and stability of vegetation (e.g., trees and exposed tree roots). Vegetation located on bank areas will be documented to establish pre-construction conditions.

The Phase I data evaluation report will identify potential bank areas that may require remedial actions and additional detailed inspection during Phase II. Phase II results will be presented in the Phase II data evaluation report, as described in Section 7.3.

The Phase I bank inspection will be conducted primarily by boat. It will be completed for all bank areas within the upper reach within the approximately four hours around a daytime low tide (two hours before, two hours after), depending on weather conditions.

The Phase I bank area visual inspection results will supplement information gathered during the *Waterway User Survey and Assessment of In-Water Structures – Data Report* (hereafter referred to as the Waterway User Survey) (Integral et al. 2018). The Waterway User Survey included general descriptions of bank areas in some locations, with more information on banks near structures, as well as maps presenting four different types of bank conditions: armored slope, vertical bulkhead, exposed bank, and dock face. The crew performing the bank area visual inspection will review the Waterway User Survey before commencing work and will refer to existing information as needed while performing the Phase I visual inspection.

The following activities will be completed prior to the visual inspection:

- Review the Waterway User Survey (Integral et al. 2018) for existing information relevant to bank conditions.
- Check tide charts to develop a schedule for the visual inspection.
- Prepare a daily float plan that includes locations to be observed each day (and existing drawings) and communication protocols for use among the field team.

Documentation will be developed for representative sections of banks and will exclude the Terminal 117, Boeing Plant 2, and Jorgensen Forge EAAs. High-resolution photographs will be taken with a camera and DGPS receiver (to tag the photograph location). Visual observations will also be documented for representative sections of banks, providing descriptive attributes of bank area features, which may include:

- Shoreline type (e.g., armored vs unarmored)
- Armored (e.g., riprap, bulkhead) and un-armored banks
- Presence of sediment accumulated on armored slopes
- Observed bank erosion
- Observed utility crossings
- Observed outfalls/pipes
- Locations with discharge flowing from outfalls
- Navigational obstructions
- Access points (including nature and condition)
- Vegetation
- Other features of note

For armored banks, the following information will be noted:

- Type of armor material (e.g., riprap, concrete, grout mat, bulkhead)
- Estimated slope/grade

- Presence of nearby structures that may indicate waterway traffic patterns that could affect the armoring

For unarmored banks, the following information will be noted:

- Qualitative observation of unarmored bank steepness
- Presence and condition of vegetation that may stabilize the slope (note if vegetation obscures observation of the condition of the underlying slope; note if roots that may indicate bank erosion are visible)
- Evidence of erosion (e.g., over-steepened bank, collapsed bank) or conditions (e.g., surface runoff) that may promote erosion
- Presence of nearby structures that may indicate waterway traffic or current flow patterns that could affect the stability of the bank

Bank conditions and features will be described on the shoreline visual inspection form (Appendix D-3), which will be used to develop the Phase I data evaluation report described in Section 7.3. Features will be photographed, and location data, photographs, and descriptions will be recorded on the shoreline visual inspection form. If a shoreline feature is not approachable by boat due to bathymetric conditions, safety concerns, or obstructions, a DGPS offset or digitized location will be collected instead.

### *5.1.2 Phase II Focused Topographic Surveys*

Following completion of Phase I PDI activities, the Phase I data evaluation report will identify bank areas potentially within or adjacent to remedial action areas. To address DQO 11, these bank areas will be targeted for the collection of focused topographic survey data to support RD.

The proposed topographic survey methods will be detailed in an addendum to the Survey QAPP that will be prepared at the same time as the Phase II QAPP addendum. These topographic survey methods could include traditional ground point elevation data collection, the use of aerial or boat-mounted light detection and ranging (LIDAR) equipment, aerial photogrammetry, or a combination of methods, depending on site access limitations, presence of vegetation, and data accuracy and density requirements informing engineering design. Additional topographic data collection locations and methods will be evaluated in coordination with EPA.

## **5.2 Structure Inspections**

Structures within the upper reach of the LDW will be inspected during Phase I. Phase I inspection efforts will include a review of available information, comprised in the Waterway User Survey (Integral et al. 2018), to inform the scope of additional visual inspections and supplement

the existing information. Structures identified in the Waterway User Survey included piers, docks, fender piling, dolphin piles, bulkheads, and outfalls.

For structures located within or adjacent to active remedial action areas, available as-built information will be obtained and reviewed in Phase II. Detailed condition inspections (via land access, vessel, and/or dive inspections) will be conducted as needed. Structure inspections will be completed in accordance with the American Society of Civil Engineers (ASCE) manual of practice (MOP) No. 130 regarding waterfront facilities inspection and assessment.

Specific Phase I visual inspection activities will include:

- General observations of structure condition, visible physical damage, and surface deterioration or defects of structure component materials. An example structure inspection form is included in Appendix D-3. Documentation of structure engineering assessments will be included in the RD.
- Collecting information to supplement existing data in the Waterway User Survey (Integral et al. 2018), including structure identification numbers, physical descriptions of the structures observed, and notations of any discrepancies or changed conditions.
- Visually assessing access or safety concerns that may be important considerations for chemistry or geotechnical sampling in the vicinity of or beneath the structure during the Phase II PDI. If access conditions are deemed unsafe, then only a general visual inspection of the structure will be performed.

Following completion of the Phase I visual inspections, a summary of findings will be provided in the Phase I data evaluation report. The Phase I data evaluation report will append the existing Waterway User Survey (Integral et al. 2018) and will present structures' location information, relevant background information, and photographs.

Following the Phase I data evaluation report, Phase II inspection and evaluation activities will be conducted for structures that may be impacted by remedial activities. These evaluations may include more detailed condition inspections, potential structure materials sampling, and additional evaluation of equipment accessibility. Phase II inspection activities will be conducted in accordance with ASCE MOP No. 130. The results of these inspections will be documented in the 30% basis of design report.

### 5.3 Geotechnical Investigation

To address DQO 13, geotechnical sediment samples (surface and subsurface) will be collected within the upper reach's preliminary active remedial action areas, as identified in the Phase I data evaluation report, as part of Phase II investigation efforts. These samples will be tested to identify in situ and ex situ sediment strength characteristics in order to develop engineering

design and sediment management/disposal considerations. The data collection efforts will be completed using sampling equipment that are different from those used to collect the environmental samples described in Section 4. Details for the proposed geotechnical sampling and testing programs are provided in the following sections.

Geotechnical explorations will be completed using barge-mounted or land-based exploration equipment and handheld testing equipment to collect surface and subsurface geotechnical data. Sampling locations will be in the general vicinity of the Phase II subsurface sediment vibracore locations, within the preliminary active remedial action areas (as defined in the Phase I data evaluation report). Where appropriate, explorations will be conducted adjacent to bank areas and existing structures to collect engineering data that will inform structural engineering evaluations in design.

### *5.3.1 Geotechnical Investigation Design*

The specific locations, numbers, and types (surface vs. subsurface) of geotechnical samples will be presented in the Phase II QAPP addendum following evaluation of Phase I data and preliminary identification of active remedial action areas in the Phase I data evaluation report. Specific types of in situ geotechnical testing that may be performed include:

- Standard penetration testing (SPT) performed at regular intervals within select borings to identify subsurface sediment density with depth and to assess dredgeability, as described in Appendix F.
- Thin-walled undisturbed sample collection for compression and consolidation testing to evaluate consolidation and settlement as part of engineered sediment cap design, as described in Appendix F.
- Cone penetration testing (CPT) at select locations to provide a continuous subsurface profile of sediment density and strength to assess dredgeability, as described in Appendix F. As appropriate, the CPT testing setup may be supplemented with a full-flow penetrometer (FFP) that is capable of measuring the shear strength of soft sediments at a higher resolution than can conventional CPT. FFP, if used, will generally follow procedures as described in DeJong et al. (2011) (Appendix F).
- Vane shear testing (VST) to identify sediment shear strength and for use in the design of engineered sediment caps, as described in Appendix F.
- DCP testing at select locations, if appropriate, to provide in situ soil or sediment density and augment SPT and CPT data for assessment of dredgeability, as described in Appendix F.

Geotechnical explorations may also be advanced to deeper elevations than those used to collect samples to be tested for chemistry. These deeper elevations will yield data related to slope stability, sediment-bearing capacity, and contacts between different lithologic units (i.e., location of previously undisturbed native sediments).

Ex situ geotechnical testing will also be performed. Samples for ex situ geotechnical testing will be identified as described in Section 4.5.

Testing requirements, as identified in Section 5.3.2, will be used to characterize variations in sediment physical properties both laterally and vertically. The characterization tests to be conducted ex situ at the geotechnical testing laboratory are:

- Moisture content
- Grain size distribution (sieve and hydrometer) and percent fines (percent passing the US No. 200 sieve)
- Specific gravity
- Atterberg limits
- Unit weight
- One-dimensional consolidation
- Direct shear
- Triaxial compression (unconsolidated-undrained and consolidated-undrained)

The data from this ex situ testing program will be evaluated to assess the variability of sediment physical properties in each active remedial action area. The results will support the assessment of dredgeability, evaluations of sediment stability, evaluations of slope stability for temporary and permanent slopes, development of design criteria for structural stability, and potential options for dewatering, treatment, and disposal during remedial design.

### *5.3.2 Geotechnical Field Methods*

Collection of geotechnical samples and data during implementation of Phase II activities will generally require the use of a hollow-stem auger, mud rotary, or rotosonic drill rig and in situ testing equipment, such as a cone penetrometer rig, handheld vane shear device, and potentially a handheld DCP. Requirements for the collection of geotechnical samples and data are described in the following sections. Decontamination procedures and field-generated waste procedures are described in Sections 4.7 and 4.8, respectively.

#### **5.3.2.1 Station Location Positioning Control**

To meet the goals of the pre-design sampling activities, appropriate positioning control at geotechnical station locations is required. Both absolute accuracy (i.e., ability to define position) and repeatable accuracy (i.e., ability to return to a sampling station) are important. The process

for station location positioning is the same as used during sediment sampling and is described in Appendix F.

### **5.3.2.2 Geotechnical Boring Procedures and Sample Collection**

A general SOP for geotechnical borehole sampling is provided in Appendix F. It contains the procedures for SPT testing, and split-spoon sampling. SOPs may be modified as necessary to complete geotechnical borings within bank areas based on access considerations, type of equipment to be utilized, water depth, and other factors. Identification of location-specific methods for collecting geotechnical data within bank areas will be documented in the Phase II QAPP addendum.

Upon positioning the drilling vessel at the proposed location, the coordinates and other field notes regarding the sampling location will be entered onto the soil boring form (Appendix D). A water depth reading will be measured using appropriate equipment (e.g., survey rod or weighted tape) to determine the depth of water to the sediment-water interface. The water depth will be recorded on the soil boring form.

SPT blow counts will be recorded for each interval sampled, in accordance with ASTM method D1586. Disturbed samples for ex situ geotechnical testing will be collected by split-spoon sampling techniques, in accordance with ASTM method D1586. Samples will be contained in air-tight glass or plastic jars, or double-sealed in ziplock bags for transport to the geotechnical laboratory. Each sample jar or bag will be labeled with appropriate sample identification information prior to sample collection (see Section 4.5).

In addition to the split-spoon samples, undisturbed thin-walled tube samples may be collected during geotechnical drilling, in accordance with ASTM method D1587 and as described in Appendix F. Similar sample container and labeling practices will be followed for these samples.

### **5.3.2.3 Cone Penetration Testing Procedures**

An SOP for CPT is provided in Appendix F of this QAPP. CPT tests will be conducted in accordance with ASTM method D3441. CPT field data will be recorded electronically by the CPT contractor, so there is no specific field data collection form for CPT. For soft sediments, the CPT instrument may be outfitted with an FFP to record higher-resolution shear strength data, as described in DeJong et al. (2011). FFP data will also be recorded electronically by the CPT contractor and therefore also does not require a specific field data collection form. Results of CPT testing will be provided in the contractor's data report and included in the Phase II data evaluation report.

#### **5.3.2.4 In Situ Vane Shear Testing Procedures**

An SOP for in situ VST is provided in Appendix F. In situ VST may be performed from the same vessel as the geotechnical drilling or from a separate data-collection vessel. In situ VST will be performed in general accordance with ASTM method D2573. VST field data will be recorded on the vane shear field form, provided in Appendix D.

#### **5.3.2.5 Dynamic Cone Penetrometer Testing Procedures**

An SOP for DCP testing is provided in Appendix F. DCP testing may be performed in difficult-to-access bank areas in order to obtain a subsurface profile of soil or sediment density for use in engineering evaluations. DCP testing field data will be recorded on the DCP field form, provided in Appendix D-2.

### ***5.3.3 Geotechnical Laboratory Methods***

Samples for laboratory analyses will be transported or shipped to Harold Benny for geotechnical laboratory testing. Harold Benny will follow the sample handling and custody procedures described in Section 4.6 and perform testing of a subset of samples (determined by the geotechnical engineer). Table 5-1 summarizes standards, laboratory methods, sample container requirements, preservation methods, and holding time limitations for geotechnical samples. Results of geotechnical testing will be included in the Phase II data evaluation report.

**Table 5-1****Analytical Methods and Sample Handling Requirements for Geotechnical Samples**

Parameter	Method	Sample Size	Container Type	Container Size	Preservative	Sample Holding Time
Grain size	ASTM D6913	300 g	Jar or double-bagged ziplock	16 oz	--	6 months
Atterberg limits	ASTM D4318	300 g	Jar or double-bagged ziplock	16 oz	--	6 months
Moisture content	ASTM D2216	50 g	Jar or double-bagged ziplock	4 oz	cool to $\leq 4 \pm 2^{\circ}\text{C}$	6 months
Specific gravity	ASTM D854	100 g	Jar or double-bagged ziplock	8 oz	--	6 months
Percent fines	ASTM D1140	100 g	Jar or double-bagged ziplock	8 oz	--	6 months
1-dimensional consolidation	ASTM D2435	na	Shelby tube	--	--	6 months
Direct shear	ASTM D3080	na	Shelby tube	--	--	6 months
Unconsolidated undrained triaxial shear test	ASTM D2850	na	Shelby tube	--	--	6 months
Consolidated undrained triaxial shear test	ASTM D4767	na	Shelby tube	--	--	6 months
Unit weight	ASTM D7263	na	Shelby tube	--	--	6 months

Notes:

In some cases, multiple tests may be run from a sample in a single container. For example, a sample in a container for grain size testing might also be used for moisture content and/or specific gravity testing. Container requirements will be confirmed with the geotechnical testing laboratory prior to sampling.

ASTM: American Society for Testing and Materials

## 5.4 Specialized Surveys

Depending upon the results from the Phase I PDI, to address DQO 14, specialized surveys (e.g., utility, sediment thickness over armor material, and debris surveys) may need to be performed during RD to supplement bathymetric and topographic surveys and to further define site physical conditions during the engineering design phase of the project.

The design and methods used for these surveys will be documented in the RD deliverables.

## 6 Data Validation and Usability

### 6.1 Data Validation

The data validation process for analytical samples will begin in the laboratory with the review and evaluation of data by supervisory personnel or QA specialists. The laboratory analyst will be responsible for confirming that the analytical data are correct and complete, that appropriate procedures have been followed, and that QC results have been compared to acceptable limits. The project QA/QC coordinator will be responsible for confirming that all analyses performed by the analytical laboratories are correct, properly documented, and complete, and that they satisfy the project DQIs specified in this QAPP. The data validator will confirm that data qualifiers are applied to QC results that are outside of acceptable limits.

Chemistry data will not be considered final until validated. Data validation will be conducted following EPA guidance (EPA 2016, 2017a, b). Geotechnical data will not undergo data validation. Instead, the geotechnical lab is responsible for completing the testing in accordance with the appropriate ASTM standards and will report if any anomalies in the data are observed.

Independent third-party data review and summary validation of the analytical chemistry data will be conducted by LDC or a suitable alternative. All chemistry data will undergo summary-level data validation, and a minimum of 10% or one SDG will undergo full data validation. Full data validation parameters will include:

- QC analysis frequencies
- Analysis holding times
- Laboratory blank contamination
- Instrument calibration
- Surrogate recoveries
- LCS/CRM recoveries
- MS recoveries
- MS/MSD RPDs
- Compound identifications—verification of raw data with the reported results (10% of analytes)
- Compound quantitations—verification of calculations and RLs (10% of analytes)
- Instrument performance check (tune) ion abundances
- Internal standard areas and retention time shifts
- Ion abundance ratio compared to theoretical ratios for samples analyzed by EPA methods 1613b and 1668c

If no discrepancies are found between reported results and raw data in the dataset that undergoes full data validation, then a summary validation of the rest of the data will proceed using all of the QC forms submitted in the laboratory data package. QA review of the sediment chemistry data will be performed in accordance with the QA requirements of the project, the technical specifications of the analytical methods indicated in Tables 4-7 through 4-12, and EPA guidance for organic and inorganic data review (EPA 2016, 2017a, b). The EPA PM may have EPA peer review the third-party validation or perform data assessment/validation on a percentage of the data.

All discrepancies and requests for additional, corrected data will be discussed with the analytical laboratories prior to issuance of the formal data validation report. The project QA/QC coordinator should be informed of all contacts with the analytical laboratories during data validation. Procedures used and findings made during data validation will be documented on worksheets. The data validator will prepare a data validation report that summarizes QC results, qualifiers, and possible data limitations. This data validation report will be appended to the data evaluation report. Only validated data with appropriate qualifiers will be released for general use.

Toxicity test data will be reviewed internally by Windward. Data will be compared to DQIs and testing conditions listed in Section 4.12.2. EcoAnalysts will be contacted to correct any discrepancies.

## **6.2 Reconciliation with Data Quality Indicators**

Chemistry data QA will be conducted by the project QA/QC coordinator in accordance with EPA guidelines (EPA 2016, 2017a, b). The results of the third-party independent review and validation will be reviewed, and cases wherein the project DQIs were not met will be identified. The usability of the data will be determined in terms of the magnitude of the DQI exceedance.

## 7 Assessment and Oversight

### 7.1 Compliance Assessments and Response Actions

EPA or its designees may observe field activities during each sampling event, as needed. If situations arise wherein there is a significant inability to follow the QAPP methods precisely, the Windward PM will determine the appropriate actions and consult EPA (or its designee).

#### 7.1.1 Compliance Assessments

Laboratory and field performance assessments will consist of on-site reviews conducted by EPA of QA systems and equipment for sampling, calibration, and measurement. EPA personnel may conduct a laboratory audit prior to sample analysis. Any pertinent laboratory audit reports will be made available to the project QA/QC coordinator upon request. All laboratories are required to have written procedures addressing internal QA/QC. All laboratories and QA/QC coordinators are required to ensure that all personnel engaged in sampling and analysis tasks have appropriate training.

#### 7.1.2 Response Actions for Field Sampling

The FC, or a designee, will be responsible for correcting equipment malfunctions throughout field sampling, and for resolving situations in the field that may result in nonconformance or noncompliance with this QAPP. All corrective measures will be immediately documented in the field logbook, and protocol modification forms will be completed.

#### 7.1.3 Corrective Action for Laboratory Analyses

All laboratories are required to comply with their current written SOPs, laboratory QA plans, and analytical methods. All laboratory personnel are responsible for reporting problems that may compromise the quality of the data. The analysts will identify and correct any anomalies before continuing with sample analysis. The laboratory PMs are responsible for ensuring that appropriate corrective actions are initiated as required for conformance with this QAPP.

The project QA/QC coordinator will be notified immediately if any QC sample exceeds the DQIs outlined in this QAPP (Tables 4-8, 4-12, and 4-17), and the exceedance cannot be resolved through standard corrective action procedures. A description of the anomaly, the steps taken to identify and correct the anomaly, and the treatment of the relevant sample batch (i.e., recalculation, reanalysis, and re-extraction) will be submitted with the data package using the case narrative or corrective action form.

## 7.2 Reports to Management

The FC will prepare a summary email for submittal to LDWG and EPA following each sampling and survey day. The project QA/QC coordinator will also email LDWG and EPA after sampling has been completed and samples have been submitted for analysis. In these progress reports, the statuses of the samples and analyses will be indicated, with emphasis on any deviations from this QAPP. A data evaluation report will be written after validated data are available, as described in Section 7.3.

## 7.3 Data Evaluation Reports

A data evaluation report will be prepared documenting all activities associated with the collection, handling, and analysis of samples for each phase of sampling, as specified in AOC4 (EPA 2018). The reports will document the sampling events and present and interpret the analytical results. EPA comments on each data evaluation report will be reflected in subsequent deliverables, rather than in revised versions of the data evaluation reports.

The following base information will be included in the data evaluation reports:

- Summary of all field activities, including descriptions of any deviations from the approved QAPP
- Sampling locations reported in latitude and longitude to the nearest one-tenth of a second and in northing and easting to the nearest foot
- Summary of the chemical data QA/QC review
- Summary of the geotechnical data (in situ and ex situ data results)
- Results of structure inspections, including field inspection forms and structure conditions ratings
- Results of the visual bank inspection, including maps, photographs, video (if used), and detailed observations collected on field inspection forms
- Results from the analyses of field samples; included as summary tables in the main body of the report, data forms submitted by the analytical laboratories, and cross-tab tables produced from the project SQL Server database
- Copies of field logs and photographs (appendix)
- Copies of chain of custody forms (appendix)
- Laboratory and data validation reports (appendix)
- Results of focused topographic surveys and additional shoreline/bank survey data collected during Phase II efforts

Once the data in the data evaluation reports have been approved by EPA, the bioassay results and the chemistry database exports will be created from the project SQL Server database. The

chemistry data will be exported in two formats: one that is compatible with Ecology's Environmental Information Management (EIM) system, and one that is compatible with EPA's Scribe database. The bioassay data will be exported in a format that is compatible with EIM. Geotechnical data will be presented in the Phase II data evaluation report as an appendix to the document.

As described in Section 6.1.4 of the RDWP and Section 4.1 of the PDIWP (Anchor and Windward 2019a; Windward and Anchor 2019), the data evaluation reports will also contain an interpretation of the data in order to define preliminary active remedial action area boundaries, depths, technologies, and remaining data needs for the next phase.

## 8 References

- Anchor, Windward. 2019a. Remedial design work plan for the Lower Duwamish Waterway upper reach. Revised draft final. Submitted to EPA October 28, 2019. Anchor QEA, Inc. and Windward Environmental LLC, Seattle, WA.
- Anchor, Windward. 2019b. Quality assurance project plan: pre-design surveys of the Lower Duwamish Waterway upper reach. Final. Anchor QEA and Windward Environmental LLC, Seattle, WA.
- California EPA. 2009. Technical support document for cancer potency factors: methodologies for derivation, listing of available values, and adjustments to allow for early life stage exposures. Air Toxicology and Epidemiology Branch, Office of Environmental Health Hazard Assessment, California Environmental Protection Agency, Sacramento, CA.
- DeJong JT, Yafrate NJ, GeGroot DJ. 2011. Evaluation of undrained shear strength using full-flow penetrometers. *J Geotech Geoenviron Eng* 137(1).
- DMMP. 2013. DMMP clarification paper: Bioassay endpoint refinements: bivalve larval and *Neanthes* growth bioassays. Revised draft. D. Kendall, US Army Corps of Engineers; R. MacMillan, Washington State Department of Ecology; for the Dredged Material Management Program Agencies and SMS Program, Seattle, WA.
- Ecology. 2017. Sediment cleanup user's manual II. Guidance for implementing the cleanup provisions of the sediment management standards, Chapter 173-204 WAC. Draft for review and comment through July 7, 2017. Pub. No. 12-09-057. Revised April 2017. Toxics Cleanup Program, Washington State Department of Ecology, Olympia, WA.
- EPA. 2002. Guidance for quality assurance project plans. QA/G-5. EPA/240/R-02/009. Office of Environmental Information, US Environmental Protection Agency, Washington, DC.
- EPA. 2014a. Record of Decision, Lower Duwamish Waterway Superfund Site. Part 3. Responsiveness summary. US Environmental Protection Agency, Region 10, Seattle, WA.
- EPA. 2014b. Record of Decision. Lower Duwamish Waterway Superfund Site. US Environmental Protection Agency.
- EPA. 2016. National functional guidelines for high resolution Superfund methods data review. EPA 542-B-16-001. US Environmental Protection Agency, Washington, DC.
- EPA. 2017a. National functional guidelines for inorganic Superfund methods data review. EPA-540-R-2017-001. US Environmental Protection Agency, Washington, DC.
- EPA. 2017b. National functional guidelines for organic Superfund methods data review. EPA-540-R-2017-002. US Environmental Protection Agency, Washington, DC.
- EPA. 2018. Remedial design statement of work, LDW Upper Reach, Lower Duwamish Waterway Superfund site. Attachment to the *Fourth Amendment of the Administrative Order on Consent for Remedial Investigation/Feasibility Study*. US Environmental Protection Agency, Region 10, Seattle, WA.
- Integral, Moffat & Nichol, Windward. 2018. Waterway user survey and assessment of in-water structures - data report. Integral Consulting Inc., Moffat & Nichol, and Windward Environmental LLC, Seattle, WA.

- Johns DM, Ginn TC, Reish DJ. 1990. Protocol for juvenile *Neanthes* sediment bioassay. Prepared for the US Environmental Protection Agency, Region 10, Office of Puget Sound, Seattle, WA. PTI Environmental Services, Bellevue, WA.
- PSEP. 1986. Recommended protocols for measuring conventional sediment variables in Puget Sound. Prepared for the Puget Sound Estuary Program, US Environmental Protection Agency, Region 10. Tetra Tech, Seattle, WA.
- PSEP. 1995. Recommended guidelines for conducting laboratory bioassays on Puget Sound sediments. Final Report. Prepared for the Puget Sound Estuary Program, U.S. Environmental Protection Agency, Region 10, Office of Puget Sound, and U.S. Army Corps of Engineers, Seattle District, Seattle, WA. PTI Environmental Services, Inc., Seattle, WA.
- PSEP. 1997. Recommended guidelines for sampling marine sediment, water column, and tissue in Puget Sound. Prepared for the Puget Sound Estuary Program, US Environmental Protection Agency, Region 10. King County (METRO) Environmental Laboratory, Seattle, WA.
- USACE, EPA, Ecology, DNR. 1991. Decision on the suitability of dredged material tested under PSDDA evaluation procedures for the South Park Marina maintenance dredging project (OYB-2-012574) to be disposed of at the Elliott Bay open-water disposal site. US Army Corps of Engineers, US Environmental Protection Agency, Washington State Department of Ecology, and Washington State Department of Natural Resources, Seattle, WA.
- USACE, EPA, Ecology, DNR. 1999. Determination on the suitability of proposed maintenance dredged material from the Duwamish Yacht Club dredging project (1998-2-02213) evaluated under Section 404 of the Clean Water Act (CWA) for open-water disposal at the Elliott Bay disposal site. US Army Corps of Engineers, US Environmental Protection Agency, Washington State Department of Ecology, and Washington State Department of Natural Resources, Seattle, WA.
- USACE, EPA, Ecology, DNR. 2007a. Determination regarding the suitability of proposed dredged material from Delta Marine Industries, Duwamish River, Seattle, King County, for beneficial use or unconfined open-water disposal at the Elliott Bay nondispersive site. US Army Corps of Engineers, US Environmental Protection Agency, Washington State Department of Ecology, and Washington State Department of Natural Resources, Seattle, WA.
- USACE, EPA, Ecology, DNR. 2007b. Determination regarding the suitability of proposed dredged material from Delta Marine Industries, Duwamish River, Seattle, King County, for beneficial use or unconfined open-water disposal at the Elliott Bay nondispersive site. CENWS-OD\_TS-DMMO. October 19, 2007. US Army Corps of Engineers, US Environmental Protection Agency, Washington State Department of Ecology, and Washington State Department of Natural Resources, for the Dredged Material Management Program, Seattle, WA.
- USACE. 2013. Determination regarding the suitability of proposed dredged material from the Duwamish Yacht Club, Seattle, WA evaluated under Section 404 of the Clean Water Act for unconfined open-water disposal at the Elliott Bay non-dispersive disposal site. US Army Corps of Engineers.

- USACE, EPA, Ecology, DNR. 2018a. Determination regarding the suitability of maintenance dredged material from the Duwamish River navigation channel evaluated under Section 404 of the Clean Water Act for unconfined open-water disposal at the Elliott Bay nondispersive site. US Army Corps of Engineers, US Environmental Protection Agency, Washington State Department of Ecology, and Washington State Department of Natural Resources, Seattle, WA.
- USACE, EPA, WDNR, Ecology. 2018b. Dredged material evaluation and disposal procedures. User manual. Dredged Material Management Program: US Army Corps of Engineers, Seattle District, Seattle, WA; US Environmental Protection Agency, Region 10, Seattle, WA; Washington State Department of Natural Resources; and Washington State Department of Ecology, Olympia, WA.
- Van den Berg M, Birnbaum LS, Denison M, De Vito M, Farland W, Feeley M, Fiedler H, Hakansson H, Hanberg A, Haws L, Rose M, Safe S, Schrenk D, Tohyama C, Tritscher A, Tuomisto J, Tysklind M, Walker N, Peterson RE. 2006. The 2005 World Health Organization reevaluation of human and mammalian toxic equivalency factors for dioxins and dioxin-like compounds. *Toxicol Sci* 93(2):223-241.
- Windward, Integral. 2017. Pre-design studies work plan. Appendix C. Data management plan. Lower Duwamish Waterway Superfund site. Draft. Prepared for the Lower Duwamish Waterway Group for submittal to EPA Region 10. Windward Environmental LLC and Integral Consulting Inc., Seattle, WA.
- Windward. 2018. Lower Duwamish Waterway pre-design studies data evaluation report (Task 6). Draft. Submitted to EPA December 17, 2018. Windward Environmental LLC, Seattle, WA.
- Windward, Anchor. 2019. Pre-design investigation work plan for the Lower Duwamish Waterway upper reach. Draft final. Submitted to EPA August 28, 2019. Windward Environmental LLC and Anchor QEA, Seattle, WA.